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CONTENTS

Self-Portraiture: The Autobiography ..... MAX FARRAND 1

A New Theory of Combustion in Diesel Engines ..... MAX G. FIEDLER 17

Direct Processes for Making Photographic Prints in Color ..... C. E. KENNETH MEES 41

A Thermodynamic Theory of Solutions of Two Liquids at All Concentrations J. L. FINCK 51

Notes from the National Bureau of Standards 71

The Franklin Institute Notes 81

Notes from the Bartol Research Foundation 85

Notes from the Biochemical Research Foundation 88

Book Reviews 91

Publications Received 94

Current Topics 80, 95

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SELF-PORTRAITURE: THE AUTOBIOGRAPHY.*

BY

MAX FARRAND, Ph.D.,

Director, The Huntington Library, San Marino, Cal.

My immediate interest in Benjamin Franklin centers in his autobiography and was stimulated through the more or less accidental circumstance of the Huntington Library being the fortunate possessor of the original and only known manuscript of that important document. Therein lies a story that cannot be told here. One need only say that the editing of the manuscript for publication presents an intricate problem in textual criticism. While seeking a solution to that problem over several years, these questions persistently intruded: What led Franklin to write his memoirs? And what are the qualities in those memoirs that have made them one of the great autobiographies of all literature and the first great American literary classic?

You may notice that the word "memoirs" is used, for that is what Franklin always called them. The *Oxford English Dictionary* gives the date of the first use of "autobiography" as 1809 by Southey in the *Quarterly Review*.

What is said to you this afternoon carries answers to the questions propounded, having only this much weight and

* Delivered in the Hall of The Franklin Institute, January 5, 1940. This was one of the papers in the "Meet Dr. Franklin" Conference.

(Note—The Franklin Institute is not responsible for the statements and opinions advanced by contributors in the JOURNAL.)

value: they are the most acceptable the speaker has found as yet. He wishes, at this point, to express his gratitude for the suggestions and criticisms of his friend, George Simpson Eddy, Esq., of New York City, the most knowledgeable student of Franklin we have today.

Many biographies of Franklin had, of course, been examined but the autobiography is also a part of our literary heritage. So not long ago, having gathered several ideas for presentation on this occasion, I made the fatal mistake of going to the shelves where in one section were gathered a large number of histories of American literature. To my dismay I found, on looking through twenty or thirty different works, that almost everything intended to be said here had already been expressed and far better than I could pretend to put it. More than that, everything that ever *could* be said about Franklin seemed already to have been put into print. But much of it was concealed in a flood of verbiage and was scattered through a mass of hopelessly second-and even third-rate stuff. Like Gratiano's "two grains of wheat hid in two bushels of chaff: you shall seek all day ere you find them: and when you have them, they are not worth the search."

Sometime I am going to let myself go on the subject of undigested, ill-thought-out productions that are being inflicted upon a long-suffering public. Anybody can write, a goodly number can write well, but there are only a few who not only have ability but are also willing to subject themselves to the discipline, amounting at times almost to torture, that is necessary to produce a work worthy of permanent preservation. I trust I am not adding to the mess.

One is inclined to think we'd be better off, so far as our *understanding* of Franklin is concerned, if nothing had been published except James Parton's *Life and Times of Benjamin Franklin*, which appeared in 1864. Perhaps an exception might be made in favor of Sainte-Beuve's unrivalled essay on Franklin among his "Portraits." Please notice that the word used was "understanding." There is no doubt that our knowledge concerning Franklin has greatly increased, especially in recent years. I like the definition in Webster's "Dictionary" that quotes Thomas Gray: "Knowledge and intelligence . . . alone do not constitute wisdom."

Even the best of the recent lives—Carl Van Doren's readable and informative "Benjamin Franklin"—has not superseded Parton. Van Doren has brought together much from hitherto inaccessible or inconveniently located sources and has added some things that are new, and told the whole story in an attractive, not to say fascinating, manner. But in the preface he wrote, "In effect Franklin's autobiography is here completed on his own scale and in his own words." Perhaps the purpose of this address is to show that he attempted something beyond the power of any person except Franklin himself to achieve.

Apparently the correct thing, these days, to say about Franklin is that he was a child of the Enlightenment. When there is any accepted agreement as to just what is meant by the "enlightenment," we may be able to concur in the opinion that Franklin was its child. Until such time, I, for one, prefer the late William P. Trent's way of putting it—Franklin "is, perhaps, the most complete representative of his century that any nation can point to." Such a statement may be equally vague, but to me at least it sounds more comprehensible.

Trent gives as a further explanation of Franklin's immortality in the United States—that "he is a typical and unapproachable product of what his countrymen are pleased to call 'true Americanism.'"

I shall come back again and again to those estimates of Franklin as a product of the eighteenth century and the personification of what have come to be regarded as American characteristics. There are persons who go so far as to blame him for some of our present traits and qualities.

Thomas Carlyle has been quoted as saying that Benjamin Franklin was the father of all the Yankees. Charles Angoff ("A Literary History of the American People," 1931) claims that this "was a libel against the tribe, for the Yankees have produced Thoreau, Hawthorne, and Emily Dickinson." He then proceeds to castigate Franklin unmercifully and to make him primarily responsible for much that is common and vulgar in American life today.

Angoff has been cited deliberately, for he presents the point of view and even the considered judgment of some

persons. But why lay this all up against Franklin? He was essentially a child of his times, as we all are of ours. He was a product of the eighteenth century. Some fifteen years ago a prominent Englishman, so high in station that he should not be identified by name, expressed in conversation his irritation that many people complained of the so-called "Americanization of England." "All that the United States has done," he said, "is to be about twenty years ahead of England. Industrialization is inevitable with all its faults and virtues. We [i.e., the English] are simply experiencing what the people of the United States have already gone through. That isn't Americanization." So Franklin should be regarded as the forerunner rather than the author of some of our less admirable traits and practices.

Benjamin Franklin bears the reputation of having been a shrewd and a wise man. It might be adduced in support of that reputation that he showed those qualities at an early age by the choice of his parents. True, Josiah Franklin, the father, was only a tallow chandler, but he lived to be eighty-nine years old, and the mother to the age of eighty-five. In other words, he came of a long-lived and, it might be added, of an industrious stock.

This child, born [1706] at the beginning of the eighteenth century, in humble circumstances, reared in poverty, largely self-taught, altogether self-made, rose from such conditions to become one the world's great figures and literally to stand before kings. The story has all the elements of success and romance that constitute the ideal of millions of Americans.

Fortunately, it is not necessary to go into the details of Franklin's life; many of this audience are better acquainted with them than is the speaker. And so we may turn directly to the autobiography but, in doing so, one point ought to be emphasized, because it is so frequently overlooked, and that is the conditions under which the writing of the autobiography was begun.

Franklin was, as is well known, on his second mission to England; but it should be remembered also how happy he was in that country. During his previous mission, as you will recall, he communicated to one of his friends that he had spent in Scotland "six weeks of the densest happiness I have

ever met with in any part of my life." After returning to America he wrote to Mary Stevenson in 1763:

> Of all the enviable Things England has, I envy it most its People. Why should that petty Island, which compar'd to America, is but like a stepping-Stone in a Brook, scarce enough of it above Water to keep one's Shoes dry; why, I say, should that little Island enjoy in almost every Neighbourhood, more sensible, virtuous, and elegant Minds, than we can collect in ranging 100 Leagues of our vast Forests? ("The Writings of Benjamin Franklin," Ed. Smyth, IV, 194).

Benjamin Franklin was a person of importance in his world, and no one knew it better than Franklin himself. He had succeeded beyond his greatest expectations. He was not disagreeably conceited—he was pleasantly, even delightfully, vain. Franklin appreciated that, too, for in the very bebinning of his autobiography he admits that his writing will

> a good deal gratify my own *Vanity*. . . . Most People dislike Vanity in others . . . but I give it fair Quarter wherever I meet with it, being persuaded that it is often productive of Good to the Possessor. . . . And therefore . . . it would not be quite absurd if a Man were to thank God for his Vanity among the other Comforts of Life.

So it was in that humor, in 1771, at the age of sixty-five, when he was on a fortnight's holiday at Twyford with his friends the Shipleys, of whom he was very fond, that he indulged himself in something he had long wanted to do—to tell the real story of his life and to give his own explanation of his success.

Certain facts of his career were common property. Other facts were known to a few. In his memoirs Franklin is telling his son, and very probably expecting through his son to tell the world, the things that other people didn't know, and furthermore what lay back of those facts. Through the whole story runs an extraordinary analysis of the motives that inspired his several activities.

Even for such a piece of self-indulgence, Franklin carefully made out a list of topics to be taken up, which, in the copies now extant, covers three pages, seven by ten inches. The memoirs themselves were written on larger-sized sheets, approximately thirteen inches by eight, and were always inscribed in the same fashion—that is, in a long column on the

outer half of the page or on the right-hand half, leaving the other half as a wide margin for additions and corrections.

When he had written a little more than eighty-six pages in this way, he stopped. From the outline we know that he was not a third of the way through—in fact, the story had come down only to 1730; he had not reached the point of his great successes; but all that was written was evidently just what it purported to be—a story for his son and immediate family and, perhaps, if they saw fit, to be made public. It is Franklin at his best.

They are, as Van Doren has said, "the homeliest memoirs that had ever been written in the plainest language." But they are something more than that. They tell the story of a printer and shopkeeper who was infinitely bigger than his job but was not above it; of a tradesman who had risen to greatness but was not ashamed of his origin nor of his station. He never shirked any of the menial tasks he had to perform. In fact he quickly saw their advertising value. Even as a youngster—who, again forecasting later American qualities, was to become the great "publicity artist" of his time—Franklin played up these menial tasks. A passage in the autobiography is often quoted but will bear repetition:

> In order to secure my Credit and Character as a Tradesman, I took care not only to be in *Reality* Industrious and frugal, but to avoid all Appearances of the Contrary. I drest plainly; I was seen at no Places of idle Diversion: I never went out a fishing or shooting; a Book, indeed, sometimes debauched me from my Work; but that was seldom, snug, and gave no scandal: and to show that I was not above my Business, I sometimes brought home the Paper I purchased at the Stores, thro' the Streets on a Wheelbarrow.

And now to take up the qualities revealed in the Memoirs, that have made them famous. Franklin's first love was what his contemporaries called "philosophy" but we should call "science." One of the chief reasons he gave for retiring from active participation in the printing shop was to get more time to devote to his experiments. To speak of his scientific qualifications is stepping outside of my field but the ideas used are common property. The line of thought here followed is taken from Lord Jeffrey, as refined by Sainte-Beuve, and adapted to our modern parlance with the help of a scientific

friend whom the Franklin Institute has honored with its medal—Dr. Edwin P. Hubble.

Franklin was not a mathematician—that is, he was not a theorist. He was a natural philosopher, a physicist, keenly observant and everlastingly curious as to the why and wherefore of natural phenomena. He made simple, searching, decisive experiments and then by his clear reasoning was able to offer convincing demonstrations.

The prime qualification of any person who would succeed in science, or in scholarship, is the ability to disassociate himself, his feelings, and his prejudices from the undertaking in hand, so as to make thoroughly impartial and impersonal observations of facts; then, in the same spirit, to record those facts; and, eventually, if possible, to find the explanation.

That is, to me, a leading intellectual quality of Franklin—his ability to take a detached, impersonal, dispassionate point of view.

But Franklin was also interested in human behavior and, in his observations of how human beings acted, he displayed one of the rarest of all qualities. His own doings were, of course, the ones about which he knew the most, and he observes and records them with complete detachment from self. He was not in the least morbidly introspective; if anything, he was whimsically amused. Benjamin Franklin was merely one of the curious human phenomena he was studying and whose acts he was recording. Then he attempted to explain how this person had been able to function so effectively.

He succeeded, as almost no one else has ever done, and that fact is attested by the place accorded to the Memoirs in the world's esteem.

An explanation has been offered to show why the autobiography is such a remarkable human document. There still remains the question of why it is regarded as a literary classic. Franklin could tell a good story, and it is not surprising that he should tell his own story extraordinarily well. That makes a good start. He also possessed a delightful humor, which adds to the enjoyment of the reader.

At this point the interpretation here presented diverges from much of the current opinion. The difference is largely in the use of terms, but the most discriminating—and that

means the best—critics apparently do not accept Franklin as one of the great "men of letters." Franklin was the essence of practicality, the embodiment of common sense. He was always constructive, but it is claimed, and in that claim I am inclined to agree, that he was not possessed by the genius that forces men to write whether they will or no, and is necessary to produce great literature.

Sainte-Beuve was apparently making the same point when he wrote:

> Here a reflection begins to dawn upon us. An ideal is lacking in this healthy, upright, able, frugal, laborious nature of Franklin—the fine flower of enthusiasm, tenderness, sacrifice,—all that is the dream, and also the charm and the honour of poetic natures. . . . He brings everything down to arithmetic and strict reality, assigning no part to human imagination.

His writings generally were in the nature of journalism and most of them were published in newspapers. To disregard them is perhaps to treat "literature" too exclusively as belles-lettres. This is not to deny that Franklin influenced both his contemporaries and his successors in their writing in ways that we think were for their betterment, because in accord with our present-day standards. He may therefore be regarded as a "literary figure" but that hardly makes him a great man of letters, if his sole lasting contribution to literature is the autobiography. This would seem to be the substance of the opinion expressed by such recognized literary historians and critics as Henry A. Beers ("Initial Studies in American Letters," 1891); William P. Trent ("History of American Literature," 1929); and Stuart P. Sherman (in "Cambridge History of American Literature").

All of these critics, however, are agreed upon the directness and simplicity of Franklin's style. It is from the autobiography that we learn how he used the *Spectator* as a model, and taught himself to improve his writing and to express his ideas clearly and concisely. Of course, the first essential is to think clearly, and that was one of Franklin's strongest points. But anyone who imagines that clarity and conciseness in expressing one's thoughts may be achieved and learned once and for all has another guess coming. Undoubtedly many have a gift in that direction. Practice improves one

but no person has yet been born who could write continuously and consistently in a clear and concise manner. Like poetry, such writing is the product of infinite pains.

The best way to learn to write is to write and to keep on writing, provided one is critical of one's own work, which was Franklin's habit. It would seem that among the most helpful things he did for his own style was the compsotion of the maxims for *Poor Richard's Almanac*. In the compilation of these aphorisms Franklin borrowed freely from everywhere. As he himself said, "They were the wisdom of many ages and nations." But they were transmuted by him, pointed with his wit, and avoiding Latin words and obscure phrases, put into direct and simple English. They stand practically alone in the eighteenth century—the type of humor henceforth to be known as American.

There are people who complain of the broadness of some of the witticisms, and the coarseness of some of the anecdotes. Just to see if there might be any relation between the two productions, I turned to Joe Miller's "Jests," the first edition of which was printed in 1739. There was no resemblance. In comparison with the Jest-Book, "Poor Richard" might well be used as a textbook in a young ladies' finishing school.

Franklin's method of composition and form of written expression, laboriously acquired in his youth, developed in all his newspaper writing, sharpened by the sayings he gathered and prepared for "Poor Richard," undoubtedly had much to do with the wide acceptance of the results of his experiments in electricity. He also found a worthy opportunity for their use to advantage in giving the account of his own life.

There are the final qualities—the simplicity of presentation and the crystal clearness of the style—that, in the flood of memoirs deluging the eighteenth century, raised Benjamin Franklin's story to preëminence.

Some things the autobiography does not reveal. Nothing is said about Franklin's social life. Apparently to him there was little that was new or of interest in the story of a simple, frugal household. But nevertheless there are certain features of consequence in understanding and forming a correct estimate of the man.

Society with a capital S didn't know him. Aristocratic Philadelphia seems to have refused to recognize him socially, although it, especially the menfolk, found him useful and indeed essential in public enterprise. That didn't bother Franklin. He cared less for Society than Society did for him. I doubt, however, if he ever realized one particular thing he had missed: It is a great pity that in his early impressionable years Franklin was not privileged to have had acquaintance and friendship with cultivated and refined womanhood. What the effect might have been is pure speculation, but that it would have been of benefit to so observing and receptive a youth, eager to improve himself, seems beyond question.

The same social inexperience might account for Franklin's failure to develop the art of conversation. The lack is generally recognized, and many references might be quoted to that effect. He was a good listener, but his contribution to social conversation and even to more serious discussions consisted frequently in telling a good story—humorous and apt. And how characteristic that is of Americans today!

We also get no hint of one of Franklin's most lovable traits—his fondness for children and his delight in companionship with young people. Van Doren has brought these out admirably. His affectionate nature, his gentleness and whimsicality, are displayed to the best advantage in letters to his young friends. Theodore Roosevelt said of his own "Letters to His Children," "I would rather have this book published than anything that has ever been written about me." So one wishes that Franklin's letters to young people might be permitted to tell their own story and reveal his attractive and natural self, without a trace of the tradesman's expediency that alienates many people.

The first part of the autobiography is the best, so far as self-revelation is concerned, not only because Franklin enjoyed doing it and let himself go, but also because "the child is father to the man" and the first part covers the character-forming years of his life. The later parts, however, have their own significance.

For over ten years nothing was heard of what Franklin had written. It is doubtful if more than a very few knew of its existence. In the meantime he had returned to America,

and after the outbreak of the War for Independence he had been sent as a commissioner to France. His incredible reception by the French and his astounding popularity, when he was the idol of Paris and crowds blocked the streets to see him, are too well known to bear repeating. His fur cap was just another piece of clever publicity, when he had to give up wearing a wig because of an eczema of the scalp.

Just as the peace negotiations were drawing to a close, Abel James wrote from Philadelphia that the memoirs commenced at Twyford had come into his hands. He begged Franklin to go on with them, and enclosed a copy of the outline, as a reminder of what was still to be done. Franklin turned the letter over to his young friend Benjamin Vaughan, with a request for his opinion. Le Veillard, the mayor of Passy, with whom Franklin had developed a warm friendship, was also consulted. They and others urged him to continue the story of his life.

But even with the conclusion of peace it was not until 1784 that Franklin again took up the autobiography. When he resumed writing he inserted Vaughan's reply along with James's letter. They make a disconcerting break in the flow of the narrative, but evidently were put in to justify the resumption of the story and to emphasize the change in the character of the memoirs. Franklin prefaced the letters with a note that the first part of the account of his life was written for the family and that the following was "intended for the public." And what a difference there is! Franklin was now over seventy-eight years old. He was not merely a man of consequence; he was one of the great figures of the world. Science may have been his first love, but the passion of his life was the improvement of others as well as of himself, and even in his greatness he never forgot it. Where this motive came from is not clear. It may have been from his New England Calvinistic training but whatever its sourve it certainly was one of the great forces in his life.

Accordingly, when Franklin again took up the autobiography, he was no longer writing the simple story of his life, for the benefit of his son: he was consciously preaching virtue, as exemplified in his own practices and experience; he was writing to instruct youth.

The value of the second part consists in the revelation of his methodical plan for "arriving at moral perfection," and in the calm way he describes his own deficiencies and limitations. You remember that Franklin listed thirteen virtues and determined to give strict attention to the practice of each of them successively for a week at a time. His reference to this systematic plan of self-improvement as "a Course compleat in Thirteen weeks, and four Courses a Year," sounds very modern.

Through all of the second part one feels a greater emphasis than was noticeable in the first instalment that others might well profit by his example.

Franklin returned to America in the summer of 1785. On the eve of sailing from Southampton he said in a letter to a friend: "I purpose, on my voyage, to write the remaining notes of my life, which you desire." Instead, he wrote three of his most extensive and useful essays: one on navigation, another on smoky chimneys, and the third a description of his smoke-consuming stove. So for one reason or another he kept putting off the continuation of his memoirs.

He had long been troubled with gout, but for several years he had been suffering from a more serious and painful malady —stone in the bladder. He has been quoted as having said that, during the last two years of his life, he had not had two months, in all, of freedom from pain. In December of 1787 he fell down the steps leading to his garden. He was badly bruised, his right wrist sprained, and the shock was followed by a severe attack of the stone. Not long afterward he began to put his house in order for the end which he saw inevitably approaching. He made his will, which bears the date of July 17, 1788. When the continuation of the autobiography was taken up, Franklin made a note in the margin of the manuscript: "I am now about to write at home, August, 1788."

The third instalment of his memoirs, then, was not commenced until after he had made his last will and testament. He was well on in his eighty-third year and was suffering grievously—to such an extent that he was forced at times to the use of opium. He was apparently engaged for several months in writing this part. He did the best he could, but

he was an old man and his story shows the effects of age. One misses, particularly, the spontaneity and the zest with which Franklin had commenced his memoirs. At Twyford he was writing almost gleefully, reliving his youth. In Philadelphia he was making a forced effort; only at times could he forget himself in the interest of the story he was telling.

But there is a quality revealed in the third section that had not appeared so clearly before. Many writers refer to Franklin's frugality. That isn't especially characteristic of him. It was truer of Mrs. Franklin. Franklin's success in his printing shop and other activities—so great that he could retire at the age of forty-two—was due not to economy but to his business efficiency. He was also quick to see and seize an opportunity. When those abilities were combined with an extraordinary insight into human nature, it is little wonder the achievements were remarkable.

The third part of the autobiography describes the emergence of a tradesman into a man of affairs, the growth of a citizen of local importance into a person of consequence throughout the colonies, and into a scientist of reputation not only in England but also on the Continent

Franklin knew his life was nearly over and that he would never finish his memoirs. Accordingly, in 1789, he had his grandson, Benjamin Franklin Bach, make two "fair copies" of so much as had then been written. One was sent to Vaughan, and the other to Le Veillard. The original manuscript, with its many corrections, was interlined, confused, and in places difficult to read. At some stage in the copying, changes were made. This statement is positive, for, although neither of these copies is now to be found, the evidence in support of it is convincing. To what extent these changes were made or approved by Franklin will probably never be known.

Sometime before his death Franklin added seven and one-half pages to his memoirs. This is the fourth and last part, and for present purposes its chief significance is due to its not being included in the copies sent to Vaughan and Le Veillard.

Franklin died in 1790. His grandson, William Temple Franklin, was made his literary executor. Years passed, and

Temple Franklin failed to bring out the promised edition of his grandfather's works. He was probably absorbed in various land speculations from which he expected large profits. It was no small task to select from and to edit his grandfather's papers. He is said to have found particular difficulty in transcribing the manuscript of the most important of all the documents—the autobiography. On one of his visits to Paris, in 1791 or 1792, he saw the fair copy that had been sent to Le Veillard and finally gave the original manuscript in exchange for it.

Temple Franklin's edition of his grandfather's works at last appeared, in 1817–18, in London. In this edition the autobiography was printed from Le Veillard's copy, in which, as Ben Bache made it, the wording had been changed in many places. You will remember also that this copy was sent before the fourth part was written, and so did not include it. The Temple Franklin edition became the accepted version of the autobiography and remained so for fifty years; it was copied, reprinted, and translated hundreds of times.

When John Bigelow was American Minister to France in 1865 and 1866, he started inquiries that resulted in the location of the original manuscript, which he finally purchased. Bigelow was greatly excited over what he found. A comparison of the manuscript with the Temple Franklin version showed many variations, and revealed, also, the neglected fourth part. He at once started to prepare what he believed would be the definitive text of the autobiography, and it was published in 1868. The entire autobiography was printed in English for the first time seventy-eight years after Franklin's death.

Bigelow intended to copy the manuscript carefully and exactly—at least he so declared. He left the spelling just as it was because he thought it showed the handicap under which Franklin had labored in the lack of early education. Spelling, however, in the eighteenth century, especially in the early part of the century, was a matter in which it was permitted to be temperamental. One might spell words very much as one chose. On the other hand, Bigelow took the liberty—and what is still more inexcusable according to our standards, without saying so—of changing both punctuation

and capitalization, points upon which Franklin as a printer was very particular. Furthermore, the copying must have been intrusted to an incompetent or inexperienced secretary. The results were appalling.

Bigelow retained possession of the manuscript of the autobiography for some thirty years and then disposed of it to Dodd, Mead and Company, who in turn sold it to E. Dwight Church. In 1911 the manuscript passed, with the rest of the Church library, into the collection Henry E. Huntington was making.

All four parts of the original manuscript were written on folio leaves of approximately uniform size. Many years later these were mounted on guards and bound in boards, with a red-leather back. The binding is evidently of French workmanship—an inference that is confirmed by the spelling, "Francklin," in the title on the back of the cover. The mere transcription of the text is not an easy task, because of numerous corrections and interlineations, but that difficulty is insignificant in comparison with the uncertainty as to what Franklin wished the final wording to be. It is doubtful if he himself knew. When he sent the copies to Vaughan and Le Veillard, he made the "earnest request" that they should read them critically. He asked them to advise him as to whether or not the memoirs should be published and, if so, what changes should be made, for, he added pathetically, "I am now grown so old and feeble in mind, as well as body, that I cannot place any confidence in my own judgment." The changes of wording in the "fair copies" prepared by Ben Bache were made, I am inclined to believe, under his grandfather's instructions. Temple Franklin's text was based on one of these copies. We also have two French translations that bear directly on the problem. One of them is of the first part only and was evidently taken from a copy and not from the original. The other is of the entire autobiography, and the translator made use of both the original and a copy.

The Huntington Library is preparing what Van Doren properly calls a variorum edition, in which all the several possible readings will be placed together upon the same page. But let me put your minds at rest upon one point. None of these uncertainties affects anything of real importance. They re-

late only to questions of style, occasionally touching the picturesque wording of a phrase or sentence—nothing more.

The Memoirs will stand as we know them—an unsurpassed story of how a printer and shopkeeper in Philadelphia rose to be one of the world's great figures, and "the most complete representative of his century that any nation can point to," while underlying the whole narrative runs a dispassionate self-analysis that only could be made by an impersonal, impartial scientist or scholar, and has never been excelled, if it has ever been equalled.

A NEW THEORY OF COMBUSTION IN DIESEL ENGINES.*

BY

MAX G. FIEDLER,

Vice-President, Fiedler-Sellers Corporation.

Lecture before The Franklin Institute of Philadelphia, on Thursday evening, May 4, 1939, at 8:15, by Max G. Fiedler, Vice-President of the Fiedler-Sellers Corporation, W. Chattin Wetherill, Vice-President of The Franklin Institute presiding.

Subject: "A New Theory of Combustion in Diesel Engines."

CHAIRMAN WETHERILL: The meeting will please come to order. Mr. Secretary, is there any business?

SECRETARY: No, sir.

CHAIRMAN WETHERILL: If not, it becomes my great pleasure to present to you the speaker of the evening. He is going to talk to us on the new theory of combustion in Diesel Engines, and I am right here to say that that is no mean assignment. Anyone who can come forth with a new theory in this day and generation certainly has my profound respect, and I am sure he will have yours, also.

Max G. Fiedler is a native of Germany. He is a graduate of the Berlin University, 1920, where he specialized on internal combustion engines. He came to America in 1928 and he brought with him some of the engines that he had been working with, over there. He brought these engines to the laboratories of the Scientific School of the University of Pennsylvania. Professor Sloan of that laboratory, who is in the audience, tonight, has very vivid recollections about it—before the meeting is over, I hope he will make his contribution.

The results of these tests that were performed at the University of Pennsylvania were very convincing. Mr. Fiedler was not a charlatan, and as a result of these experiments his

* Presented at a meeting held Thursday, May 4, 1939.

work has attracted the interest and the attention of most of the important minds in the internal combustion fields since that day.

Mr. Fiedler has now associated himself with the Fiedler-Sellers Corporation, where he has been taken into the firm—and again, that is no mean achievement. Therefore, I can assure you, Ladies and Gentlemen, that Mr. Fiedler comes to you tonight—even though he comes with a new theory of combustion for Diesel engines—he comes carrying a good deal of scientific weight in back of it. I am sure there are going to be some of you who will disagree, because of your preconceived ideas on this subject, with what he has to say. After all, he made a remark, coming to the lecture this evening, that I thought quite important. He said, "It is extremely difficult to try to convey in 45 minutes what has taken me 20 years to find out."

Now I believe Mr. Fiedler has something important to tell us. I hope that when he gets through with what he has to say you will feel entirely free to discuss this matter. That is the purpose of The Franklin Institute—to afford you that opportunity—and Mr. Fiedler, I am sure, joins me in the expression of that hope. Therefore, Ladies and Gentlemen, it is with the greatest of pleasure that I present to you at this time Mr. Fiedler, the Vice-President of the Fiedler-Sellers Corporation, who is going to talk to us on a new theory of combustion in Diesel Engines.

MR. MAX G. FIEDLER: Mr. Chairman, Members of the Institute and Guests: I am quite overwhelmed, not only by the introduction that I received here, but also by the large attendance. I did not think that anything I had to say would arouse so much interest.

I want to thank The Franklin Institute for giving me the opportunity to talk to you tonight, and I want to thank you for coming. As you know by the invitation, I am going to talk about the Diesel engine, the prime mover that has ever since its conception received a tremendous amount of publicity.

You will also, I think, recognize from the invitation that I do not quite concur with you in the high opinion of the Diesel engine and the large amount of credit that has been

given to that type of prime mover—anyhow, not up to date. In fact, my personal opinion is that that type of prime mover has been a great disappointment. I have had this opinion for quite some years, but I did not think that the time was ripe to present it to the public. I do think, today, that the Diesel engine is at the turning point. In spite of all the publicity and all the good will, money and research that have gone into that type of prime mover, it has not produced accordingly. It will either have to produce in the future or it will disappear from the world, as an engine.

Now I could give you what I have to say in the form of a paper. I could give you the facts and the high points in my paper and you would go home and say, "There is another fellow who read a paper"—you would just stick it in your pocket and forget about it. Therefore, I have decided upon a different method. There is enough tragedy and disappointment in the development of that prime mover that it is worth telling in the form of a story, in fact in the form of a mystery story—that is really the better expression because: Why has the Diesel engine never produced?—Why has it always been a half-way affair?

I would like to ask that you be as open-minded as possible. I might say things tonight that may offend some of you. That, of course, is not my purpose. I have only one thing in mind and that is to bring to your attention what I know, as plainly and as easily for you to understand as possible.

If you are to talk about the Diesel engine, of course you have to start with Dr. Diesel. The high point is that Dr. Diesel conceived his idea after a lecture on Thermodynamics by Professor Linde. It took him time to get it clear in his mind before he presented his theories about the ideal heat-cycle to the engineering world.

Now a very peculiar thing happened—a rather unusual thing: Contrary to usual practice, Dr. Diesel was accepted right away; he was acclaimed. His explanation, his theories and his mathematical proof were so tremendous that nobody had any doubt that he was correct. He received, also—which is unusual—immediate financial backing, tremendous backing. In fact, the richest man in Germany backed him, and thus he was able to build the first engine.

This first engine was destroyed by an explosion. Now right there the history is rather hazy—the general engineering conception was that he was going to extremes, that he was using the highest possible pressures and that naturally an explosion could happen under those circumstances, and this could destroy the engine. I would like you to keep that in your minds—that there is an analysis already accepted by the engineering world that an explosion can destroy a Diesel engine.

The next big mystery is Dr. Diesel's death. He died by drowning. Some stories have it that he was murdered; some say that he committed suicide. The story that he was murdered is very unlikely. The idea in back of that is that he was perhaps giving away information to England, which information he should have given only to his own country, Germany. However, there was no logical reason for murdering him. All of his ideas and his theories were widely printed; there was no secret about them.

He had not proved himself to be a successful designing engineer. For some reason, however, his Diesel engine right away received a tremendous amount of credit. For example, it is generally believed that the Diesel engines were the cause of the success of the German submarines. The first submarines and in fact the most successful one during the World War was the U-9 driven by a hot bulb, kerosene engine. It was only later that the Diesel engines were installed in submarines.

That is the story of Dr. Diesel in a few words. Instead of telling you more about Dr. Diesel, I am obliged to talk about myself. I don't like to do that, but I have, for some reason, been introduced into this Diesel problem. I did not do it by choice. A few high points at the beginning of my life are interesting perhaps because they fit into the clues we want to analyze later on.

I served with the German Navy during the World War and I was attached to a formation that had a great number of different types of patrol boats—we called them "Submarine Chasers"—which had gasoline engines, hot bulb engines and Diesel engines.

I remember one incident: I was assigned to a boat which had two air-injection Diesel engines. On the first trip out we operated only on the starboard engine. I asked about the other. The answer was that we only needed one on that trip and that the other wasn't any good, anyway. I said, "What is wrong with it?" They said, "We don't know, but every time we start it something happens."

Well, I just couldn't leave that engine alone, and against orders, one day, after I had looked it over carefully, I started it, with very tragic results. One man was almost killed—the cylinder head was blown off the one engine, and the relief valve caused considerable injury to my assistant. There was a big investigation and the investigation as usual brought out everything except that in which I was interested. Why was the engine destroyed? It was brought out that I was much too young to handle a power plant like that, and that it was against orders. But, finally, the storm blew over.

I was not satisfied in my mind, however, and I went to the Chief. I went into the Lion's Den, and asked for permission to ask a question. In the German Navy you needed permission to ask a question. My question was: "What happened?"

The Chief looked at me—I will never forget that look; it was the most surprised look—and said, "You gave that engine too much fuel," and before I had a chance to say, "Well, now, the explosion occurred before she had any fuel at all," I was dismissed—and that was the end of that chapter.

Now this analysis is still good today. You ask a Diesel engineer, when you get a violent knock in starting the engine, and he will tell you that the knock is due to too much fuel. But let's think it over for a moment. We know, from experience with gasoline engines, that under certain conditions, sometimes even at starting, all the fuel that can possibly be consumed can be set off in an engine and still doesn't wreck the engine. But the Diesel engineer comes along and says: "You put too much fuel into the cylinder which causes a violent reaction and destroys the engine." This just doesn't seem logical. This contradiction between the things that we have learned in gasoline engine experience

and the popular conception of Diesel combustion was first impressed on my mind during my naval service.

I later joined the naval air force. I am telling you all this just to illustrate the fact that I was again in a branch of the service in which motors were predominant. And, when the war was over, and while I was still studying, I designed an engine which I thought in those days was better than anything on the market.

To start out, I am going to begin with that engine, because it is the basis of all my future designs.

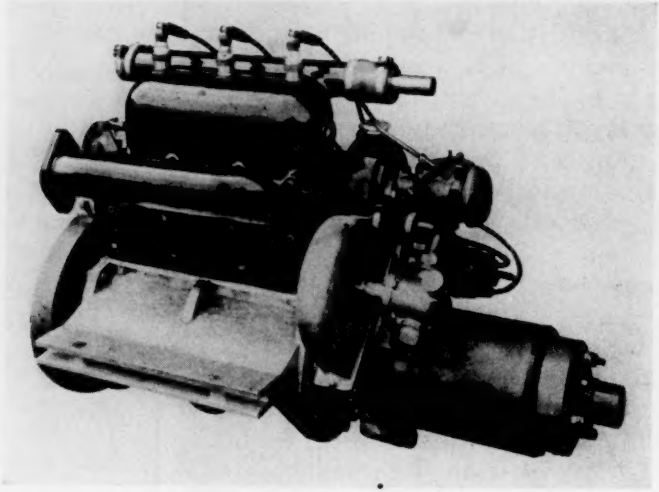

FIG. 1.

Fig. 1. This engine was designed for a light car, in Germany. The displacement is 61 inches and it delivered 30 h.p., which is quite a remarkable performance. The front end that you see here is a little disturbing—that is a marine conversion, and the extension in front is an electric reversing unit. This means that this engine does not need a reversing gear. Simply by pressing a button it will go backwards and forwards. This little engine was brought out commercially, and was a success—there is no doubt about it. It was brought out in a little car designed by myself

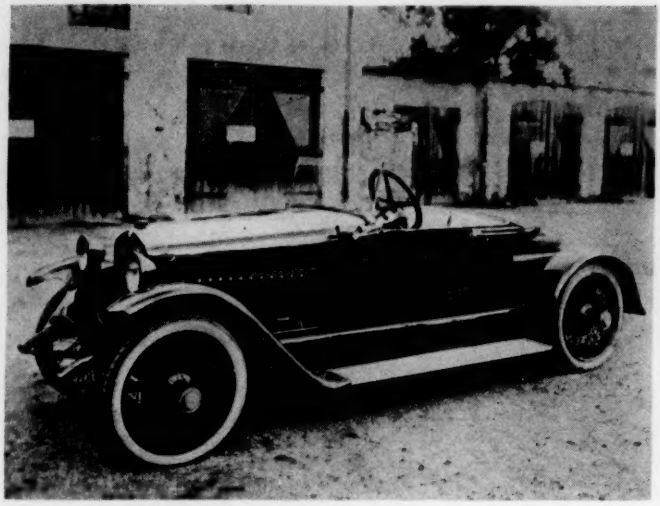

FIG. 2.

in 1921, and as you see, this car still looks rather nice—that is, it is not too out of date (Fig. 2).

Now to give you an idea of the performance of this engine (Fig. 3). This curve was published in 1924 by

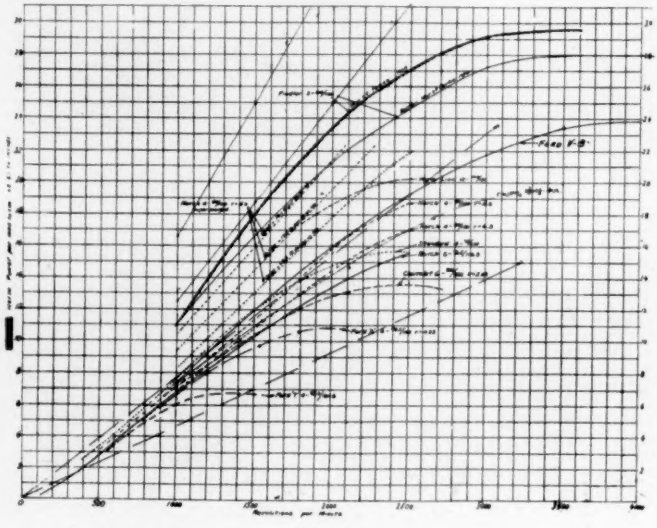

FIG. 3.

Professor Becker, of the Technische Hochschule Berlin Charlottenburg. He had investigated a lot of engines and he added the performance curve of my engine on this data sheet with a lot of other engines, and we have, since then, added other motors to it.

CHARTS: Here you see the old Model "T" Ford. I want to remark that these are all reduced to the same displacement,

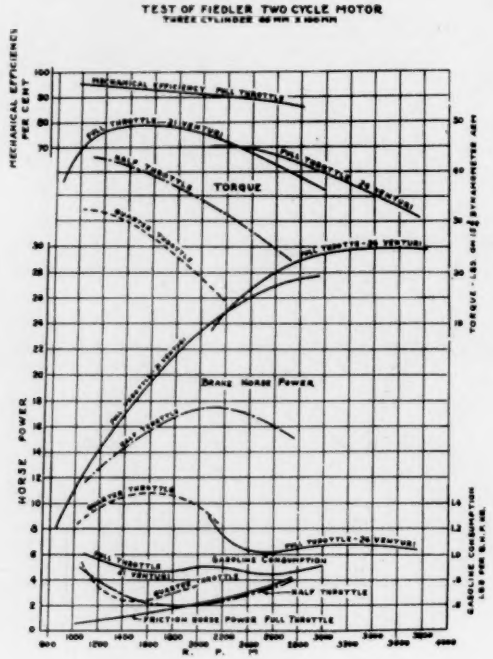

FIG. 4.

61 cu. mm. Then there is the Model A, and there we have a Chevrolet—compression ratio of five to one. Then the Buick up there; and there is a modern German engine, overhead valves, tested with a ratio of 4.3 and 5.6 to 1. These lines up here are for the same engine supercharged with one-tenth, two-tenths, and three-tenths of an atmosphere.

Here we have a very late curve of the Ford V-8, and at the top you see the power curve of the 3-cylinder engine. That curve up there is a test run by the University of Berlin

in 1924. I brought some of these engines over and had them tested over here, and they performed a little better than abroad. I think this was due to the better gasoline we have over here, that is, the gasoline that was available in 1929.

Fig. 4. Here is an interesting thing; this is the latest test on that same 3-cylinder engine. You will see from these curves that the engine is sensitive to volumetric efficiency. You see that the size of the venturi in carburetor at high speed has a definite effect on the power output.

This was a problem for us to overcome, if we wanted an improvement in power at higher speeds (Fig. 5). I designed

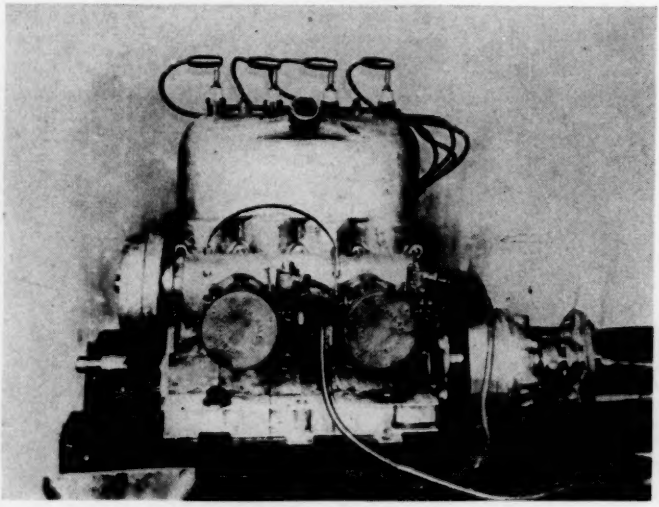

FIG. 5.

another engine that should have had high volumetric efficiency at higher speeds. This engine was commercially a complete failure, not because it was designed wrong, but, turning up to 8,000 revolutions per minute, being a 2-cycle engine, the magneto had to turn up to 16,000 revolutions. At that time there was only one magneto that could accomplish this, and then only spasmodically. You also see that the carburetors are out of proportion to the size of the engine. Nevertheless, the engine developed 80 h.p. with only 90 cu. in. displacement. As I said before, however, this engine was a failure. We

tried to overcome the problem of volumetric efficiency by doing away with the carburetors and tried gasoline injection. This was in 1926. We didn't know, however, at that time, how to handle gasoline injection properly, and it didn't work out very satisfactory as far as regulation was concerned. We finally decided on mixture injection. We provided for a separate cylinder, which would draw in a mixture of air and gasoline, and inject this charge into the main cylinder, thus overcoming the difficulties with the carburetion. From this design eventually evolved the Diesel with which we have been experimenting in recent years.

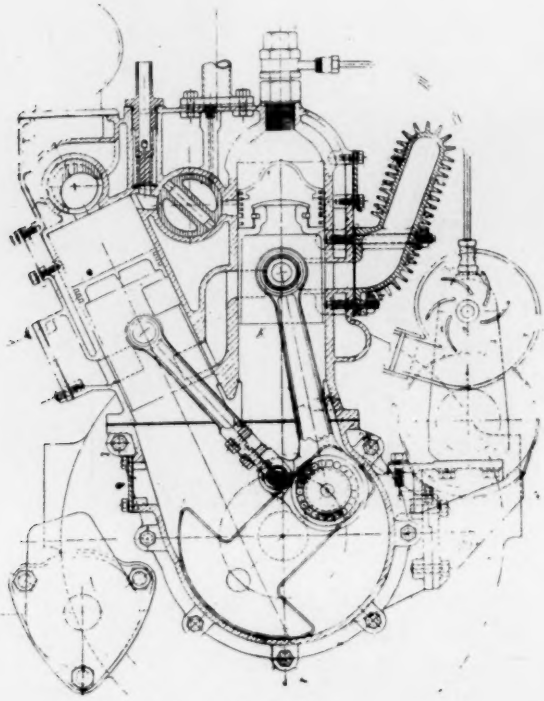

FIG. 6.

Figure 6 shows a cross section of that Diesel engine. On the left side is the supercharging cylinder, while the scavenging air furnished by both cylinders is compressed in the crank case. Combustion occurs only in the right cylinder.

Fig. 7. The engine itself is an automotive engine designed in 1929 and 1930, and that engine at the start was a complete failure. The failure was due to something that started us on the track of some research work that we have been doing in the past nine years, and which has become so very important. If you realize that in this engine design I had incorporated ten years of experience, you can imagine how heart-breaking the moment was when the engine started with a roar, and at the same instant the pistons would come out of the exhaust like a magnesium flare. Well, the answer

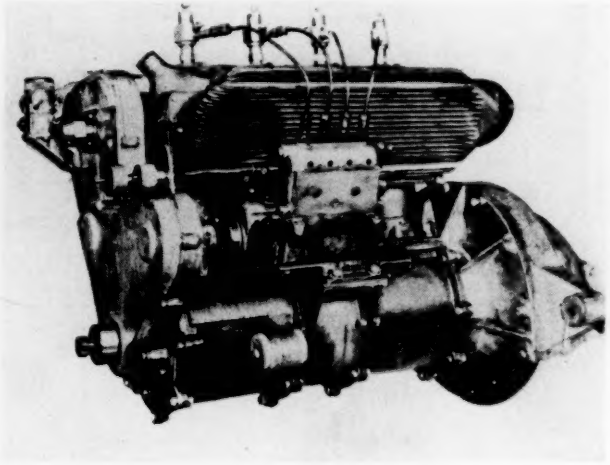

FIG. 7.

of the engineer was: "That man is crazy—in the first place, a 2-cycle engine cannot be cooled adequately; in the second place, he is supercharging it highly; and in the third place, he is making it a Diesel which is still worse, so the whole thing is absolutely impossible."

We ran about 200 sets of pistons through the engine, none of which lasted more than five seconds. Then I decided that the standard accepted theory was not correct. If there had been a high load during the time the pistons burnt, I would have understood it, but the pistons would come out even when the engine was still idling.

So, for this reason we started out on a new investigation. We first prepared the engine for all eventualities. We capped the pistons, installed special lubricators, and then we decided we would need an indicator in order to find out what happened inside the cylinder. The first indicator we put on was destroyed the moment the engine started. We hunted around and decided on the use of a Maihak Highspeed Indicator. There is an interesting story connected with that indicator. Some of you may have recognized cards like this one (Fig. 8).

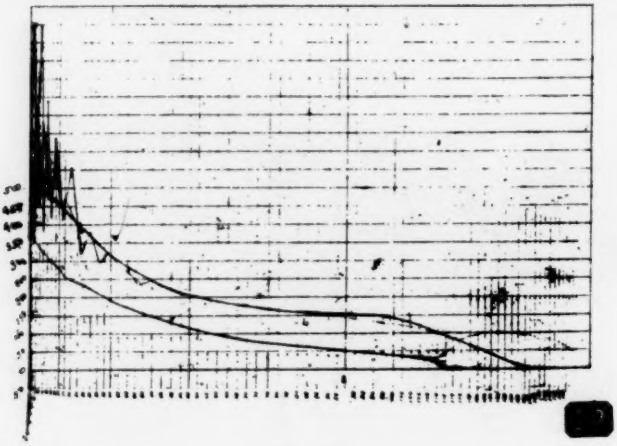

FIG. 8.

However, inasmuch as the paper is stationary at that point of maximum movement of the stylus, the pen scratches the paper and either breaks the arm or the paper flies off. The accepted explanation for those lines you see here is that they are caused by indicator vibrations—that is what the Diesel engineers said.

I was not convinced by this explanation. The indicator vibrations were not in any relation to the natural frequencies of the instrument. We therefore conducted some rather careful tests which convinced us that the indicator was trying to show us something that we apparently did not want to see.

Fig. 9. This card 90° offset shows the same characteristic. The dead center, however, is not at the left-hand side of the

card but in the center. The vertical lines represent degrees crank angle; the horizontal lines, pressure. The line at the top represents piston movement through upper dead center. Through this relation between indicator and engine, the indicator drum moves very fast during the time of combustion, which makes it easy to study the pressure in the cylinder at this vital point of the cycle.

These three cards are taken with the same indicator but with different assemblies. The one card is a 1 to 1, the next a 3 to 1; and the other a 2 to 1 piston assembly. You

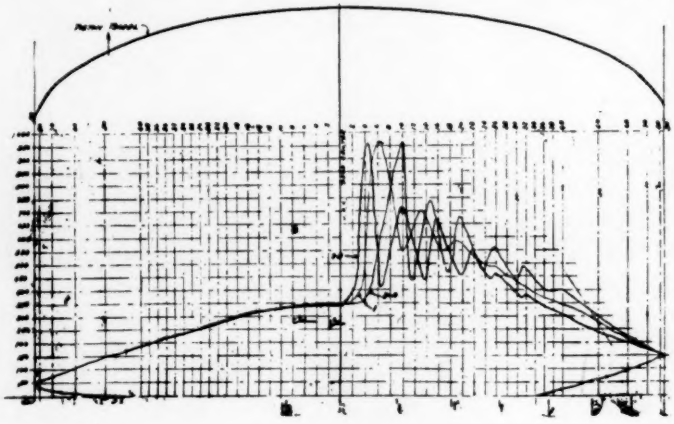

FIG. 9.

see that these cards can be pushed almost on top of each other and show absolutely identical characteristics. We put them out of phase so that this could be better distinguished.

We made another check—we put the same indicator on a variable compression engine and started to jack up the compression until the indicator would show these pressure variation lines. They appeared instantaneously when the so-called Diesel knock was noticeable. So we were convinced that the instrument would show us something. I don't say it gives absolute readings, but you use an instrument in research work to show some condition that you can analyze. If the indicator shows a definite characteristic for knock, and another characteristic for no-knock, then it presents an indication of the conditions we want to investigate.

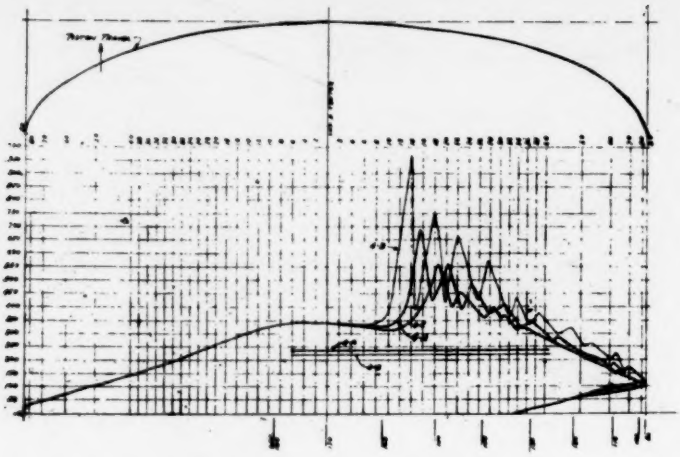

FIG. 10.

Fig. 10 shows a few loads on the engine with the standard injection valve. This is a valve or nozzle of standard recommendation. In other words it has an opening pressure of 3,000 lbs.; maximum injection pressure of 5–6,000 lbs. The holes are 3/10's mm. and the atomization according to the Diesel engineer's specifications, which should result in a

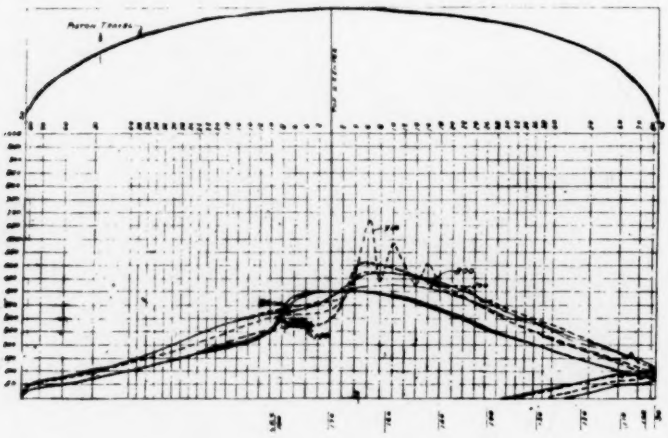

FIG. 11.

smooth combustion. However, the indicator shows very violent pressure reactions.

Then we take another card (Fig. 11) and all of a sudden the indicator shows something different. Now this was depressing because the nozzle in this latter case didn't fit the engine at all. We tried to change the characteristic by advancing the injection, and to our surprise it just dropped the peak pressure. The line marked 900 shows a change due to higher engine speed that was mystifying. The next card we tried to superimpose a diagram (Fig. 12) on a straight

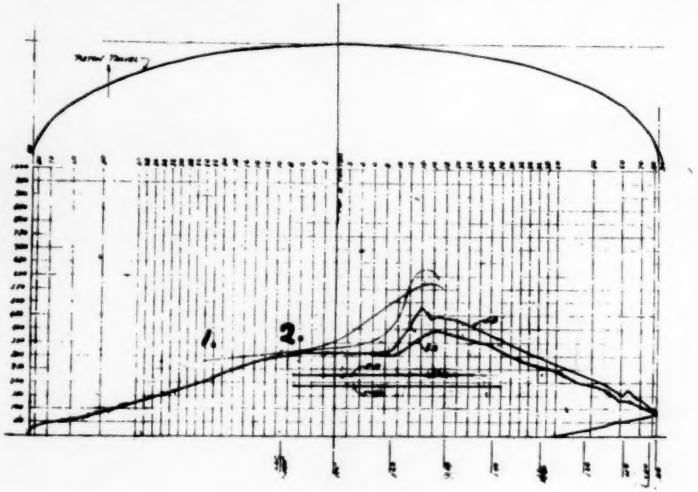

FIG. 12.

gasoline engine with one spark plug. Point 2 is the ignition point of the same engine with 5 spark plugs firing, and you get the corresponding pressure lines. You see that with more ignition points you get a sharper pressure rise, but you do not get the knock so typical of Diesel engines.

So the analysis that the rate of normal pressure rise is responsible for knock is also wrong. Then we started experimenting with changes in duration. There were indications that the combustion would not really start until the end of the injection, and we attempted to shorten the duration.

Figures 13 to 26 report checks on various injection characteristics.

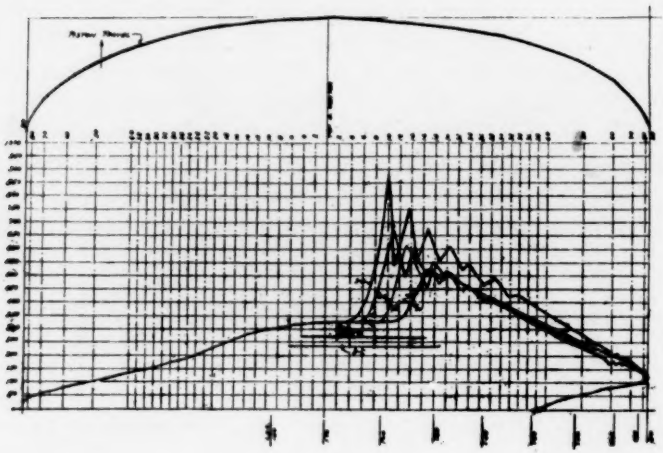

FIG. 13.

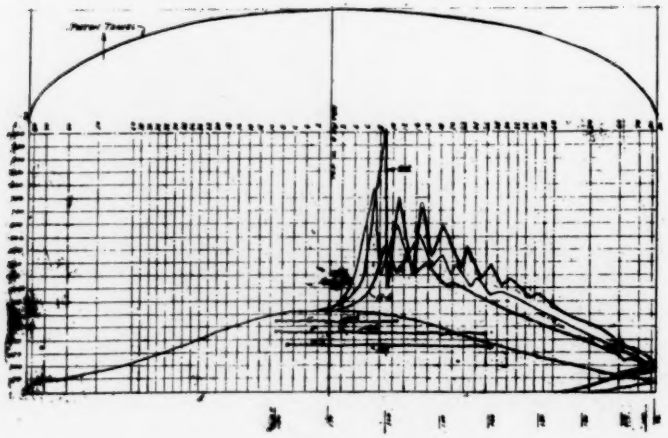

FIG. 14.

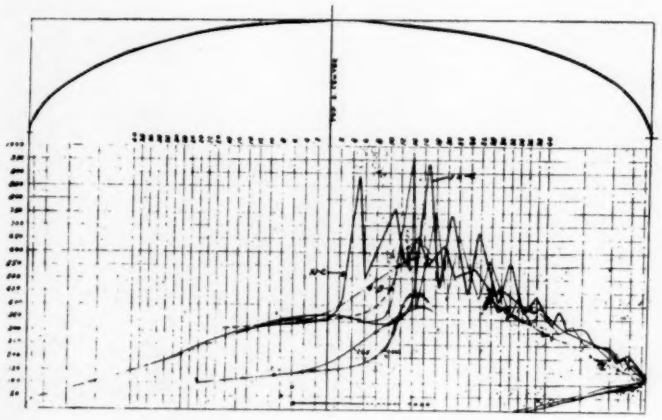

FIG. 15.

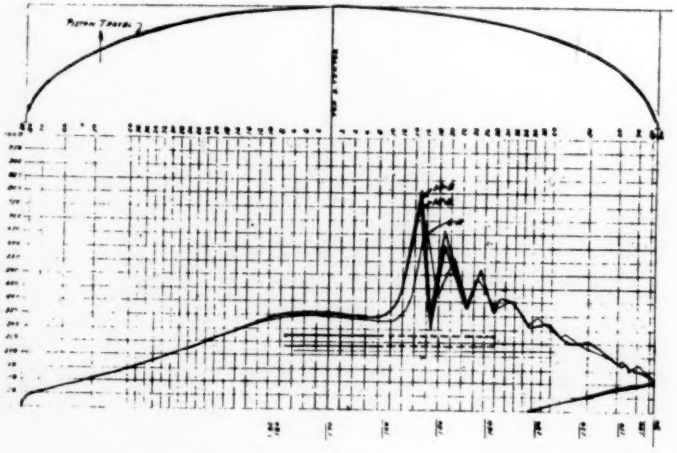

FIG. 16.

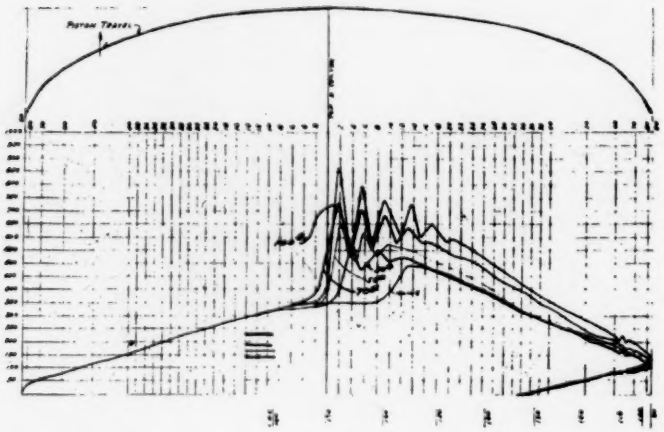

FIG. 17.

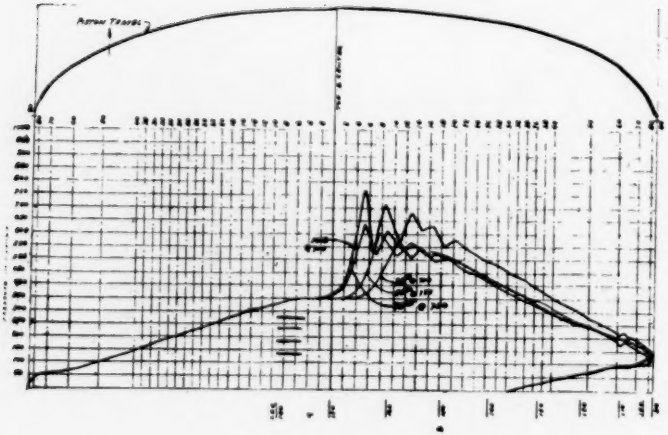

FIG. 18.

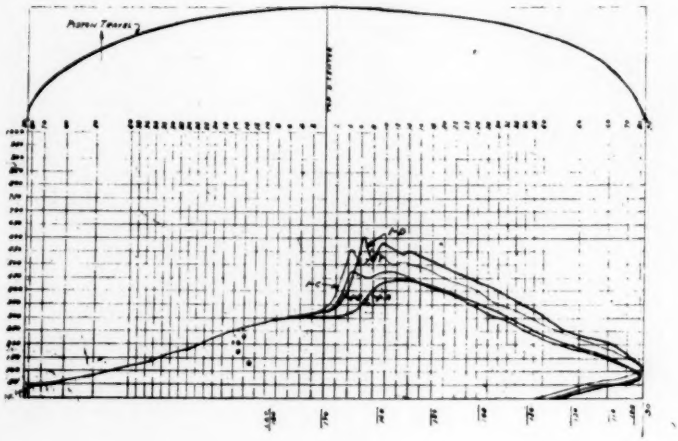

FIG. 19.

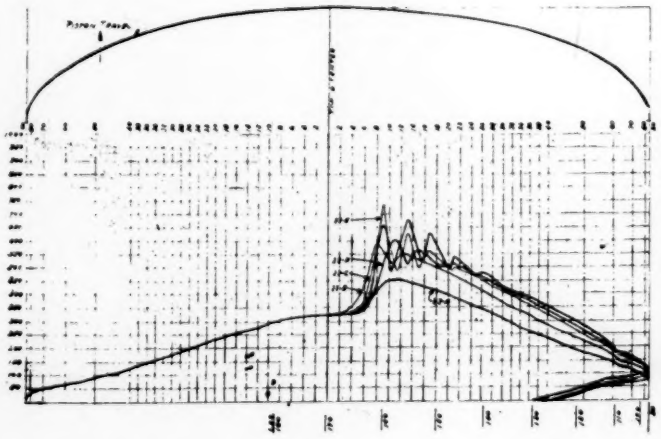

FIG. 20.

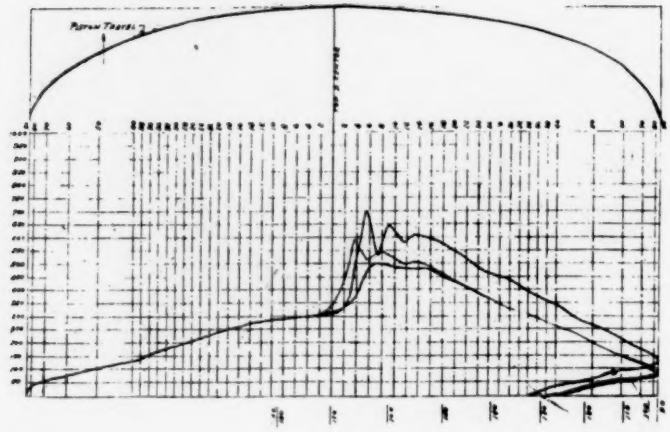

FIG. 21.

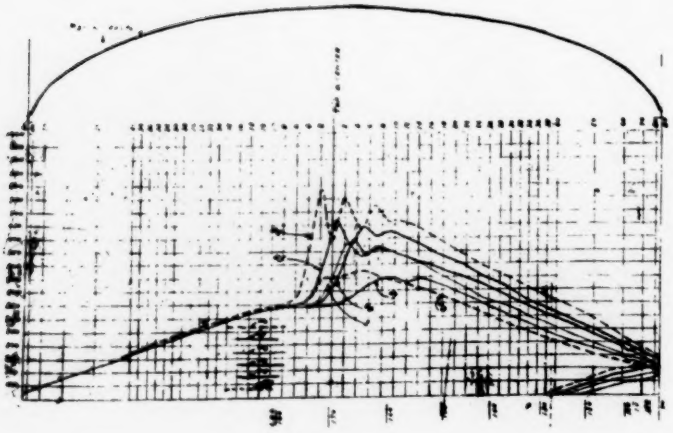

FIG. 22.

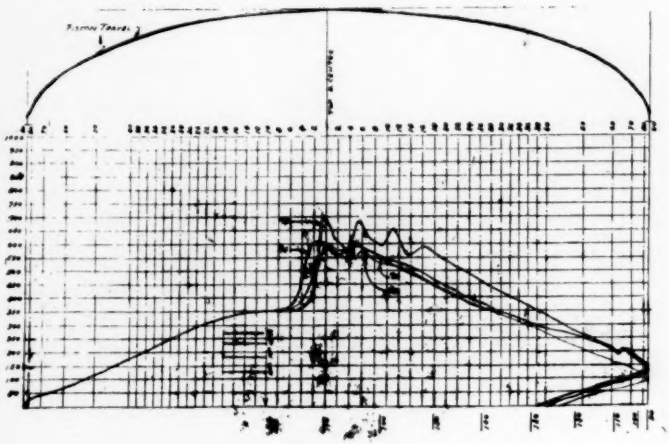

FIG. 23.

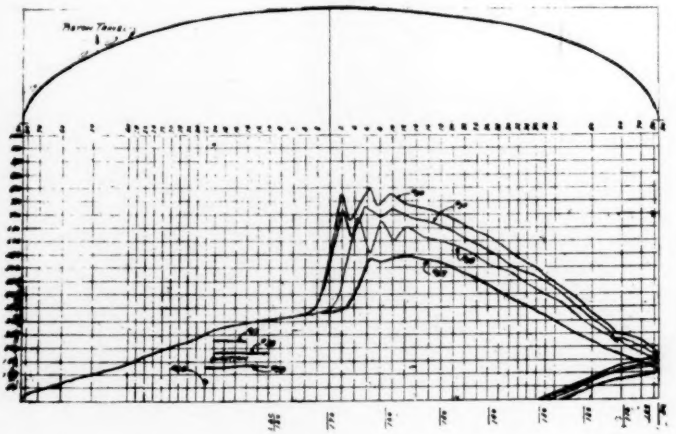

FIG. 24.

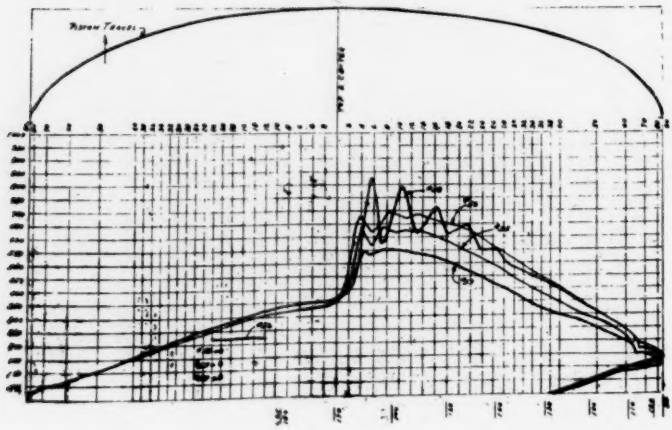

FIG. 25.

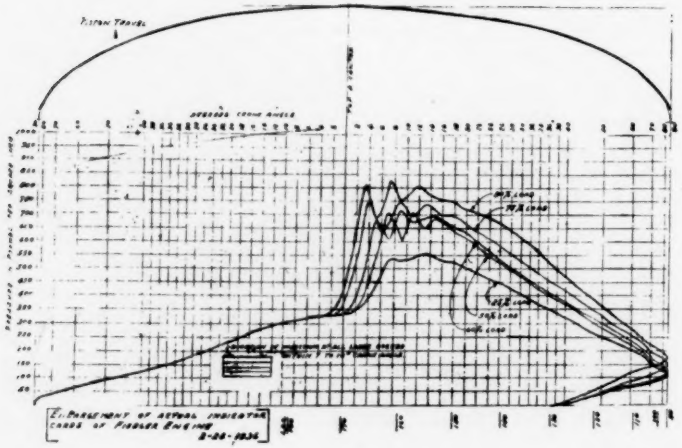

FIG. 26.

Fig. 13. Multiple hole nozzle, 1,800 lbs. opening pressure.

Fig. 14. The same nozzle but higher opening pressure. *Knock is more pronounced due to higher pressure and greater degree of atomization.*

Fig. 15. Check on rate of pressure rise for violent knock. *Rate not more than in gasoline engine without knock.*

Fig. 16. Long duration and high injection pressure. *Causes ignition delay and in combination with fine atomization strong knock.*

Fig. 17. Phase cards with short duration and medium nozzle pressure. *Combustion characteristics good at low loads but disappointing at higher loads.*

Fig. 18. The same conditions but change in orifice. *Gives improvement.*

Fig. 19. The same valve but change in combustion chamber so spray is located farther away from cylinder walls. *Decided improvement.*

Fig. 20. Same condition with increased injection pressure. *With increase in atomization, combustion becomes worse, knock stronger.*

Fig. 21. Same condition but larger orifice; meaning less atomization. *Decided improvement.*

Fig. 22. *More improvement due to increase in orifice length; better penetration and mixing of fuel in air.*

Fig. 23. *Less spray holes gives improvement in spite of higher injection pressure:* fewer ignition points.

Fig. 24. *More improvement due to still larger and longer holes.*

Fig. 25. *Further improvement with same condition due to very heavy injection spring:* better control of injection.

Fig. 26. Shows best performance at that date.

This investigation showed that to get good combustion everything had to be done that was contrary to generally accepted practice.

First—the spray holes had to be kept very large. In this case, for a fuel quantity injection per stroke of 100 cu. mm.—6 holes of .8 mm. diameter were used. The holes had to be especially long. A length-diameter of approximately 8 to 1 was used. Due to very heavy special springs, the injection pressure for all loads could be kept as low as 1,200 lbs. per sq. in.

(*To be continued in February issue.*)

Navy's Drydock Plants Grow Apace With Fleet.—The Navy Department announced recently that its construction of dry-docks, many of which are designed for building as well as repair of great capital ships, is keeping pace of the two-ocean Navy program. In fact the needs of the fleet have been anticipated in the dry dock construction program, and the docks are ready to service the growing Navy as needed. This particular job is under the cognizance of the Bureau of Yards and Docks of which Rear Admiral Ben Moreel, U. S. Navy, is Chief. At Philadelphia, finishing touches are being placed on one of two giant docks, capable of docking any of the nation's battleships built or building. These like other of the major dry docks are being equipped with batteries of great cranes capable of picking up any unit of installation on a battleship. Operations adopted were designed to cut off a year and a half from the time it ordinarily takes to build such docks. Effort is now being made to cut this time even further. The major part of the great job was done under water through what is known as the "Tremie Method," whereby concrete is poured into its position, leveled by underwater drags except for refinement carried out after the job is freed of water. The hundreds of workmen involved do not see their handiwork until weeks or months after it has been done. Divers working down under water's surface guide those above surface. Hydrostatic pressure—the pressure pushing up from underneath the surface of any pumped-out area—is generally a major problem to be overcome in construction of dry-docks. It is for this reason primarily that the underwater process of laying concrete floors and submerged portions of sidewalls was developed and improved, for by this method the pressure from underneath is neutralized by the weight of the water pressing down from above. At Long Beach, California, where the Navy is building a major drydock the earth structure was such that the entire excavation could be carried out in "the dry" simply by sinking some 30 wells down through the foundation area and keeping pumps going. In this way hydrostatic pressure was prevented from building up. Marine railways are also a part of the drydock system. One at Key West is already being used. It will handle destroyers and other craft up to around 3,000 tons.

R. H. O.

DIRECT PROCESSES FOR MAKING PHOTOGRAPHIC PRINTS IN COLOR.*

BY

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During the last few years, the public has shown a greatly increased interest in color photography. A few years ago, the introduction of a direct method of making color transparencies made the practice of color photography very much easier than it had been, and at the present time a very large number of photographs are taken in color. Approximately three-quarters of the home motion pictures are made in color, and more than twenty million still pictures are being taken in color this year. I think that if I were to ask the average man in the street, however: "What is the status of color photography?", he would say: "Oh, you can make photographs in color, but we have not yet got real color photography." And if I cross-examined him as to his meaning, I should find that what he was thinking about was the production of prints in color; that he felt that to achieve real "color photography," it should be possible to load a camera with a film and then, after the film was developed, to obtain from it a color print, just as a black-and-white print is obtained from an ordinary film exposure.

Color prints are being made, but by processes which involve a great deal of expense and difficulty, and so the objective of real color photography—to make prints in natural colors from a color transparency by some simple, direct process—has remained unattained. Within the past year, however, it has been achieved not by one method but by two different methods. An account of these new processes is given in this paper.

Processes of color photography involve invariably the preparation of three pictures, each taken by one of the pri-

* Communication No. 832 from the Kodak Research Laboratories.

mary colors—red, green, and blue-violet—and then their recombination to form the final color picture. To produce color prints, the pictures are combined in the form of dye images, each of the images being formed of a dye having a color complementary to that by which the picture was taken. The picture taken by red light is printed in a cyan (blue-green) dye, the picture taken by green light is printed in a magenta dye, and the picture taken by blue is printed in a yellow dye. The three separate pictures may be taken successively through suitable filters or simultaneously in a somewhat complicated *one-shot* camera, in which a system of reflectors splits the light from the lens to form three images, or by means of a *tripack*.

The early development of tripacks is dealt with in Chapter IV of E. J. Wall's "History of Three-Color Photography." [1] He ascribes the first suggestion to Ducos du Hauron, from whom came suggestions for almost all the systems of color photography which have been developed. In 1897, du Hauron described an "Apparatus with a single dark slide and with a single objective procuring the simultaneous obtainment of the three phototypes; in other words, dialytic selection of the light rays by an alternation of color filters and plates or sensitive films, formed like the leaves of a book or polyfolium, placed in the dark slide." In this system a pack of three films and a yellow filter are used. The objection to these tripacks is poor definition. The light passing through the front film becomes diffused, and since this is necessarily separated from the green- and red-sensitive layers by the thickness of the film base, it is difficult to get really sharp pictures. To get the real advantage of a tripack, it is necessary for the three sensitive layers to be almost in contact; that is, the three layers should be coated one over the other so that the distance between the blue and red layers is a small fraction of one-thousandth of an inch. Tripacks of this type were suggested in the early literature of color photography with the idea that they should be separated into the three layers for development and printing, but the manipulation of such systems proved in practice to be very difficult, and they had no success.

[1] Published by the American Photographic Publishing Company, Boston, Massachusetts.

It was also suggested, however, that it might be possible to develop such tripacks and then by some chemical treatment to convert the silver images into dye images. There are a number of proposals of this type in the early literature; one of the earliest which appeared possible of realization was that made by Rudolph Fischer in 1912. Fischer proposed that a tripack should be made by coating three emulsions on the top of one another, the lowest one being sensitive to red light, the middle one sensitive to green light, and the top one sensitive to blue light, and that in these three layers there should be incorporated chemical substances which in the process of development would produce dyes. The method which Fischer proposed to use for producing dyes was one which had been discovered by Homolka and worked out by Fischer himself—the process which we now know as *coupler development.*

This depends upon the fact that when a developer reacts with silver bromide and forms silver, its oxidation product as it is formed reacts with other chemical substances in the solution and forms colored compounds; that is, dyes. This is true only of certain developing agents, particularly those known as *diamines.* When the diamines develop silver bromide, their oxidation products formed at the same time combine with many types of chemicals which are known as *couplers* and give rise to strongly colored dyes which are depositied in the film with the silver formed by the development of the image.

The details of the mechanism of dye formation have not been completely established, but it is believed that the first reaction occurs between the developer and exposed silver halide to produce silver. In this reaction, the developer is oxidized to an extremely reactive intermediate product, which immediately reacts with the coupler. This second reaction probably forms the leuco dye, from which the dye itself is generated in a subsequent oxidation step. The choice of developing agents for color-forming development is very limited. All of the known types of organic developers have been investigated, and, of these, only certain p-phenylenediamine derivatives have been found useful. These consist of p-phenylenediamines bearing two substituents on one of the ni-

trogen atoms. Other substituent groups may be introduced into the benzene nucleus to modify the properties of the developer itself or of the dyes derived from it.

The couplers are distinguished chemically by their possession of a reactive group, usually methylene. The cyan couplers are usually phenols; thus, a typical compound would be a chlorinated naphthol. Magenta couplers are often nitriles or pyrazolones, and the yellow couplers are typically esters, ketones, or amides. The couplers may be added to the developing solution, in which case they must be of relatively low molecular weight and be soluble in the alkaline solution, or they may be incorporated in the emulsion layer. In the Fischer process, the couplers were incorporated in the layers, each coupler in its appropriate layer, so that during development three different dyes would be produced simultaneously—a cyan dye in the red-sensitized layer; a magenta dye in the green-sensitized layer; and a yellow dye in the layer sensitive to blue and violet. In this process, it was necessary that the sensitizers should not wander from one layer to another and also that the couplers should remain in the layer in which they had been placed. In the existing state of knowledge, Fischer and his collaborators were unable to accomplish this and so were unable to realize his very ingenious process.

The first workers to succeed in producing direct color photographs by a tripack which reached the commercial market were Mannes and Godowsky, to whom the Institute awarded its Edward Longstretch medal in 1940. They adopted coupler development, but instead of putting the coupler into the emulsion, they introduced the dyes into the appropriate layers during the processing, the original tripack consisting of the sensitized emulsion layers only. This process was worked out by Mannes and Godowsky in association with the Eastman Kodak Company, and in 1935 it was placed on the market under the name of *Kodachrome*. It was introduced first for 16-mm. film for the amateur cinematographer. Since then, its use has been extended to cover the low cost 8-mm. motion-picture film, the 35-mm. still film for miniature cameras, and cut-sheet film of large size for use by the professional and commercial photographers.

To produce the three color images in Kodachrome, it was necessary to find a method of introducing each dye image into its own layer. The image in the bottom layer, sensitive to red, must be formed of the blue-green dye; the middle layer, of the magenta dye; and the top layer, of the yellow dye. In their original Kodachrome process, Mannes and Godowsky took advantage of the position of the layers. The process uses a film in which there are five coatings: Nearest the base is coated the red-sensitive layer and over this an interlayer of gelatin. Above this is coated a green-sensitive emulsion, which is overcoated with an interlayer of yellow dye to act as a filter. Finally, there is a blue-sensitive emulsion at the top. All the five coatings are very thin, and the total thickness of the emulsion is little more than that used in ordinary film. To transform the three images into the dye positives, the film was first developed to a negative and the negative silver images removed by bleaching with permanganate. The film was then exposed to light to make the positive silver bromide images developable, and the whole film was developed to produce a blue dye in all three layers. Then the film was dried and, in a second machine, was treated with a bleach of low penetration, the action of which was limited to the two top layers, from which the dye was removed and the silver bromide regenerated and developed to a magenta color. The film was dried again, and a bleach of very feeble penetration removed the dye from the top layer and turned the silver in that layer back to silver bromide, so that it might be developed to the yellow dye. This process was slow and very clumsy because of the three separate treatments required, but it was, nevertheless, successful and was operated for some years.

A new process was then worked out in which the assigning of the dyes to their correct layers depends not upon their position in the depth of the film but upon the sensitivity of the three emulsions. It was necessary, of course, that the sensitizers should survive the early stages of processing, and since no sensitizer would withstand the action of acid permanganate, it was necessary to use a different reversal process.

In this process, the exposed film is put through an ordinary developer to produce a silver image. Then the film is

exposed through the base to red light, which makes developable the unexposed silver bromide in the bottom layer, and this is developed with a cyan coupler, so that in the bottom layer a positive image in cyan dye is associated with the development of the whole of the silver bromide originally present in the layer. Next, the top side of the film is exposed to blue light and is passed into a developer containing a yellow-forming coupler. Then all the silver bromide is exhausted except that corresponding to the positive image of the middle layer, which is developed with a coupler forming a magenta dye. There are then in the film three positive images in the appropriate colors and the whole of the silver bromide converted into silver by the two development operations which each layer has undergone. The silver is removed from all three layers, and the film is fixed, washed, and dried. This process offered very considerable difficulties when it was first attempted but, in view of its advantages, they were overcome, and it is the method by which the Kodachrome film is now processed.

A great many improvements have been introduced into the original Kodachrome film by changes in the sensitizers, in the couplers, and in the dyes that they produce. The original Kodachrome couplers formed dyes which on long keeping tended to fade, especially at temperatures above normal. This trouble has been largely eliminated, and unless the present Kodachrome images are exposed to conditions of elevated heat and moisture, they are unlikely to show any appreciable fading over a reasonably long period. The quality of the images has also been improved by steady adjustments of the many points involved until, at the present time, the Kodachrome process may be regarded as a very excellent and reproducible system for obtaining color transparencies.

It is obvious that the Kodachrome process could be used to obtain color prints. If a Kodachrome transparency is laid down on white paper support, it will appear much too dark to make a good print, but a transparency too light and transparent to be satisfactory for viewing by transmitted light can be cemented to a white paper support and the film base removed by solvents, which leaves the color image on the

paper. It is also obvious that it should be possible to coat the three sensitive layers on an opaque base, such as paper, and to process them by the Kodachrome process to get a color print, but this is a far more formidable task than would appear. The mere duplicating of a Kodachrome is not very easy. It is difficult to avoid a loss of color saturation and a shift in color. Moreover, the thin coatings on paper give new troubles of their own, and the paper base itself introduces very considerable difficulties. These can be overcome by using a white opaque film base instead of paper.

As a result of a good deal of work, the Eastman Kodak Company was able to announce at the end of August last that they were prepared to make color prints from Kodachrome transparencies. Three kinds of prints were made available in this program at the beginning of September.

Those known as *Minicolor* prints are made from the small Kodachrome transparencies on 35-mm. film which have been so very successful in the hands of the general public. The transparencies are enlarged two diameters to make an inexpensive print or five diameters to make an enlargement which can be placed in a standard photographic mount. Thousands of these $2\times$ and $5\times$ color prints are being made every week. At the same time, commercial prints from larger Kodachrome originals are made by a more complicated process, in which an improved color correction is obtained by the introduction of masks over the original. These masks are black-and-white negatives printed on panchromatic film from the original color transparency. The mask is fastened to the original in accurate register, and, being a negative, it lowers the over-all contrast of the picture. In addition, the color of the light by which the mask is printed is chosen so that the greens and blues, which tend to become too dark in the print, are lightened. In this way, a print can be made which will reproduce the original much more closely than if no mask were used. These *Kotavachrome* pictures, as they are called, can be made of very large size. Thus, one of the methods for making satisfactory direct color prints utilizes the Kodachrome process.

Some time after the first Kodachrome film was introduced on the market, the Agfa Company in Germany placed on the

market a film in which they had realized the original Fischer process. They had available sensitizers and couplers which would not wander from one layer to another and were thus able to put out a film which they processed by a reversal process.

Some years ago, the Kodak Laboratories worked out a modification of the Fischer process in which the couplers in their emulsion layers were not dissolved in the gelatin layer itself but were carried in very small particles of organic materials which would protect them from the gelatin and, at the same time, protect the silver bromide from any interaction with the couplers. When development takes place, the oxidation product of the developing agent dissolves in the organic material and there reacts with the couplers, so that the dyes are formed in the small particles dispersed through the layers. This process might be known technically as the *protected coupler* process. Its success depends upon the choice of suitable materials for protecting the couplers and, of course, upon the choice of suitable coupling compounds for the dyes. Within the last year this process has been reduced to a production basis, and early in 1942 a new film will be introduced suitable for use in roll-film cameras except those which are already supplied with the 35-mm. Kodachrome film. The film will be developed as a complementary negative from which prints on paper can be made by the same process. This process has been named *Kodacolor*, a name which was used some years ago for the additive process of color photography by which the first amateur color motion pictures were made. This process is now obsolete, as it was withdrawn when Kodachrome was introduced.

This new Kodacolor process, then, differs very markedly from Kodachrome although it is essentially of the same character. The film is coated with the light-sensitive layers: the red-sensitive layer nearest the base; then the green-sensitive layer; a filter layer; and the blue-sensitive layer. In each of the emulsion layers are suspended particles of organic compounds insoluble in water, particles so small that they can be seen only under a high power microscope and containing the couplers required to produce the dye appropriate to each layer when they react with the oxidized developer. After exposure,

the film is processed with a developer of which the oxidation product reacts with the three couplers, each in its own layer, and thus a dye image is produced with the silver image in each layer. After the silver has been removed, a negative is obtained composed of dyes, in which the image is not only negative as regards light and shade but in which all the colors are complementary to those of the original subject. When such a negative is printed upon a paper coated with a similar set of emulsions containing protected couplers, a color print is obtained in which the colors of the original subject are reproduced.

The Eastman Kodak Company is undertaking to process and print the Kodacolor film. The purchaser of a roll of Kodacolor film can send it to a processing station through his dealer and order color prints from the negatives that will result from his exposures. The prints are made by projection and are of the same width regardless of the size of film used. They are made on a special projection printer adapted to enlarge the picture to a standard width and, at the same time, to maintain the proportions of the picture shape used. In this printing process it is not necessary to use waterproof base, and the prints are on paper. The printing is done on a continuous roll of paper, which is processed through a complicated machine, after which the prints are cut up and delivered.

The introduction of this new process, which makes it possible for the public to obtain color prints without any greater difficulty than attaches to the taking of photographs in black and white, and the development of the Kodachrome printing process, by means of which prints can be obtained from Kodachrome transparencies, mark an important turning-point in practical color photography. Just as the introduction of the Kodachrome process in 1935 enabled home motion pictures to be made in color, and in 1937 its application to 35-mm. still pictures made it possible for millions of color photographs to be made each year, so these new processes will enable color prints to be produced in rapidly increasing quantities.

It is not always recognized that the development of inventions to the practical stage often involves far more work than the original inventions which made the development

possible. The methods used in the manufacture and processing of Kodachrome were invented long before the film itself could be placed in the hands of the user, and the application of the process to the production of prints required much further work before those prints could be made with sufficient ease and certainty. But, as each new step is taken, new possibilities come into sight and new progress can be made.

The growing popularity of color photography cannot fail to affect the engraving and printing arts. As more and better color photographs are taken, the demand for their reproduction will increase and the use of color in illustration is likely to increase to a very significant extent during the next few years.

ROCHESTER, NEW YORK,
November 27, 1941.

A THERMODYNAMIC THEORY OF SOLUTIONS OF TWO LIQUIDS AT ALL CONCENTRATIONS.

BY

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I. INTRODUCTION.

This paper is an extension of the thermodynamic studies [1] made by the writer on a single gaseous phase and liquid-vapor systems. The same thermodynamic approach is made here in the study of solutions, and certain generalizations have been drawn with regard to all degrees of concentration.

At the outset we may state that the distinction between a chemical reaction and the process of solution of one substance in another is, from our modern point of view, a matter only of the degree of bonding of the respective molecules and atoms of the constituents. In some cases, as for example the solution of sulphuric acid in water, the distinction is rather meaningless. In our thermodynamic study of solutions there are two characteristics which serve, among others, as a sort of measure of the degree of the chemical bonding. They are (1) the heat evolved during the solution process, and (2) the resultant change in volume. There are also electrical changes which we shall consider.

In this paper we shall consider solutions formed of two chemically pure liquids, X and Y, and within the pressure and temperature range under consideration we shall assume that they are soluble in one another in all proportions. We shall also assume that, under this pressure and temperature range, each liquid by itself undergoes no transformation, such as freezing, so that if we write for each liquid

$$v_X = f_1(p_X, T), \tag{1}$$

$$v_Y = f_2(p_Y, T), \tag{2}$$

[1] JOUR. FRANKLIN INSTITUTE, **225**, no. 4, pp. 411–435, Apr. 1938; **229**, no. 2, pp. 201–221, Feb. 1940.

then f_1 and f_2 are assumed to be continuous and single-valued functions of their respective pressures and temperatures.

When a solution is formed, we shall treat it as a chemical reaction, and write

$$(X + Y)_\alpha \rightarrow (X \cdot Y)_\alpha, \tag{3}$$

where $(X + Y)_\alpha$ represents the uncombined liquid system, and $(X \cdot Y)_\alpha$ the completed solution. α is indicative of the concentration, which consists of α grams of X to $(1 - \alpha)$ grams of Y. The specific volume of the solution may be written as $v_{X \cdot Y}$; if $p_{X \cdot Y}$ is the pressure on this solution, we may write

$$v_{X \cdot Y} = f_3(p_{X \cdot Y}, T, \alpha) \tag{4}$$

and we assume f_3 to be continuous and single valued in the three independent variables. For the left side of (3), considered as a system of unmixed liquids, we may define its specific volume by the relation

$$v_{X+Y} = \alpha v_X + (1 - \alpha) v_Y. \tag{5}$$

In using this expression we shall consider X and Y, each at the same temperature T, but they may be at different pressures; i.e., in general, $p_X \neq p_Y$.

II. THE MIXING OF TWO LIQUIDS AS A REVERSIBLE PROCESS.

Let us imagine a set of experiments with an apparatus such as is shown in Fig. 1. This consists of three cylinders A, B, and C, each provided with a piston. Between A and B we have a membrane b which is permeable only to X in either direction. Between A and C we have a membrane c which is permeable only to Y in either direction. This entire apparatus is to be surrounded by a calorimeter, which can measure any flow of heat to or from the system, and which can also maintain the system at any desired constant temperature.

Suppose that A contains $(X \cdot Y)$ at $(p_{X \cdot Y}, v_{X \cdot Y}, T, \alpha)$, B contains X at (p_X, v_X, T), and C contains Y at (p_Y, v_Y, T). By exerting a sufficient pressure on B, X will flow from B to A; similarly, on exerting sufficient pressure on C, Y will flow from C to A. The question is—if we exert a sufficient pressure on A over that of B and C, will liquid from A flow into B and C? This question has meaning because we have

assumed the semi-permeable membranes b and c to be permeable to X and Y, respectively, but not to the associated molecules $(X \cdot Y)$. In order to make this point clear, the writer will follow the considerations of his previous paper with regard to the persistence of chemical form and the

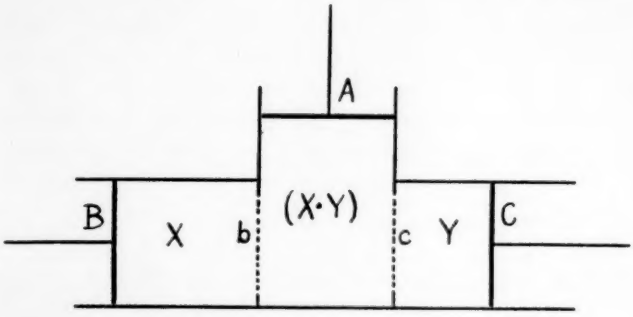

FIG. 1.

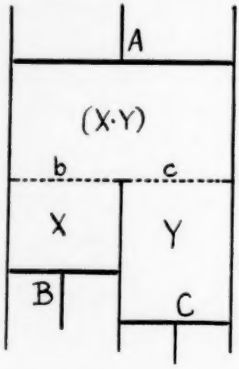

FIG. 1a.

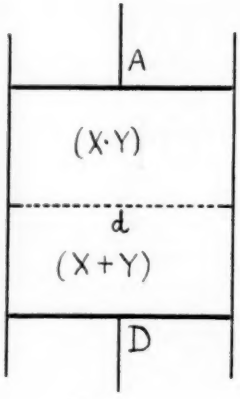

FIG. 1b.

function of a catalytic agent.[2] To repeat here, the writer has made the following two assumptions:

(1) All chemical reactions require a catalyst.

(2) In any given system of matter, it is possible by means of some catalytic agent or agents to constrain individual

[2] Loc. cit. Apr. 1938; sections II and III.

atoms and molecules to take and retain any associated or dissociated form by providing them with the necessary energy.

The reader is referred to the original paper for the discussion as to what is considered as constituting a catalytic agent. Applying these assumptions to the present case, we shall consider that we can, at will, introduce a suitable catalytic agent at b and c for any desired length of time, and cause a dissociation of $(X \cdot Y)$ into $(X + Y)$, or an association, provided of course that we at the same time supply the necessary energy. Returning then to the above question, if a sufficient pressure is exerted on A, we can by invoking this power of the catalytic agent, cause a separation of any desired portion of $(X \cdot Y)$, and allow X to flow into B, and Y to flow into C.

Consider now two modifications of Fig. 1, shown in Figs. 1a and 1b. Except for a rearrangement of the position of the cylinders, it is obvious that the system shown in Fig. 1a is functionally the same as that of Fig. 1. Let us now compare Figs. 1a and 1b. In the latter we have combined B and C into the single cylinder D, and the two semi-permeable membranes b and c into a single membrane d. Suppose that d were permeable to X and Y molecules in either direction, but not to the associated molecules $(X \cdot Y)$. If A contains $(X \cdot Y)$, the only possible way to have material pass through d into D would be to utlize our catalytic agents in the way described above. We shall also assume that just as soon as $(X + Y)$ enters A, the catalytic agent will cause a formation of $(X \cdot Y)$. Accompanying this association we will have an absorption or evolution of energy, with a resultant change in volume. Thus, by invoking the power of the catalytic agents, we see that functionally all three systems are equivalent. The only difference is that, whereas in Figs. 1 and 1a, X is under the pressure p_X and Y under p_Y, in Fig. 1b the two are mixed (although not associated in the chemical sense), and the pressure must be the sum of the partial pressures on the two components. Let us assume that, in Fig. 1b, when the entire system is at one temperature T, and there is no matter flowing across d, that the pressures on both sides of d are equal; writing for the partial pressures of X and Y, p_X and p_Y, respectively,

we shall assume that

$$p_{X \cdot Y} = p_X + p_Y = p_{X+Y} = p. \tag{6}$$

The system will then be in thermodynamic equilibrium. By increasing the pressure in D by an infinitesimal amount and for an infinitesimal length of time, we shall have a flow of an infinitesimal quantity of $(X + Y)$ into A; we then invoke the power of our catalytic agents, and $(X \cdot Y)$ is formed, accompanied by a certain energy change. Whereas in Fig. 1b we have no control over the ratio of X to Y in forming the solution, by using the forms of Figs. 1 or 1a we can produce infinitesimal transfers with any desired ratio. In other words, if in A we have a concentration α, we may cause $(X + Y)$ to enter A and combine with constant α, or we may cause X but not Y to enter A, thus increasing α in A. At equilibrium we shall assume (6) to hold for the systems of Figs. 1 and 1a as well as of 1b.

The reader will no doubt see the analogy between these systems and a liquid-vapor system. The semi-permeable membranes act as surfaces of condensation, the heat of solution corresponds to the heat of condensation, and the partial pressures as the vapor pressures.

Considering the contents of D as one system, we may write

$$v_{X+Y} = f_4(p_{X+Y}, T, \alpha). \tag{7}$$

We can also consider the entire contents of A, B, C or A, D as a single system. Let us define x as the ratio of the mass of $(X + Y)$ to the total mass of $[(X + Y) + (X \cdot Y)]$. This will be analogous to the degree of dissociation used in the previous paper.[3] For the entire system we may then write

$$v = f_5(p, T, \alpha, x) \qquad \text{or} \qquad p = f_6(v, T, \alpha, x), \tag{8}$$

where v is the ratio of the volume to the mass contained within $A + B + C$ or $A + D$. If for this system we define the internal energy ϵ as the ratio of the total energy to the total mass, and similarly for entropy η, we may also write

$$\epsilon = f_7(p, T, \alpha, x) = f_8(p, T, v, x) \tag{9}$$

and

$$\eta = f_9(p, T, \alpha, x) = f_{10}(p, T, v, x). \tag{10}$$

[3] Loc. cit. Apr. 1938, p. 415.

These equations are similar to those of equation (5) of the previous paper, except that we have here the additional variable α.

With T, α = constant, we may draw a family of curves in the (p, v) plane on the basis of equation (8), as shown in Fig. 2,

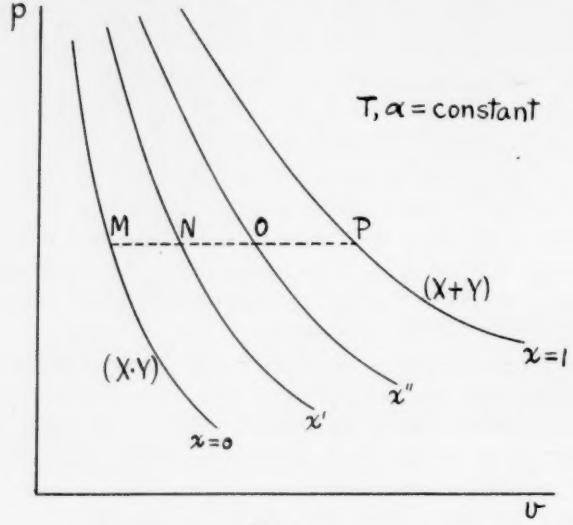

FIG. 2.

where x is constant along each curve. This family is bounded on one side by $x = 0$, where the system is completely associated or in solution, and on the other by $x = 1$, complete dissociation. Starting with the system in equilibrium, let us raise the pressure in D by the infinitesimal amount Δp_{X+Y} (or for B and C we may raise the pressures by Δp_X and Δp_Y), and cause an infinitesimal fraction Δx of $(X + Y)$ to flow into A, where with the assistance of a suitable catalytic agent they combine to form $(X \cdot Y)$. The heat may be carried off so fast that there will be no resultant change in T. We may now remove the catalytic agent and adjust the volumes of A and D so that $p_{X+Y} = p_{X \cdot Y}$ and equal to the original pressure. In this process we will have the changes $-\Delta v$ and $-\Delta \epsilon$, say, with p, T, α = constant. This process can obviously be reversed under the same constant conditions, provided we utilize a catalytic agent which can decompose $(X \cdot Y)$ into

$(X+Y)$. We thus follow the isothermal-isopiestic-isoplethoric $MNOP$, Fig. 2, and the process can be carried out in either direction to any degree of completion. The reader will note that the present system is entirely analogous to the systems considered in section II of the previous paper, except that we have here the additional variable α. It is conceivable that the lines $x = 0$ and $x = 1$ of Fig. 2 may cross at some point, and the discussions of section VI of the previous paper should apply here. In fact, the point of crossing, which would be the case of a "perfect" solution, is well known among liquids, and as we note here, it is but a singular state applying only to a certain value of (p, T).

III. OSMOTIC PRESSURE OF SOLUTIONS.

Let us consider those systems of equation (8) where $x = 0$. In Fig. 3 the solid lines represent a family of curves in the

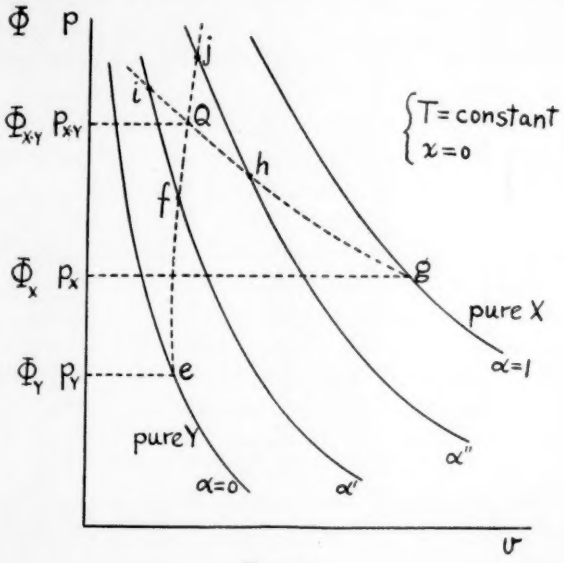

FIG. 3.

(p, v) plane where T is the same for all curves, and α is constant along each but differs for consecutive curves. This family is bounded on one side by $\alpha = 0$ (pure Y), and on the other by $\alpha = 1$ (pure X). It is hardly likely that these curves

will cross at any point, for that would mean (see equation (8)) that we should have two different solutions at the same p, T, v with $x = 0$, a condition which is highly improbable.

If our system of Figs. 1, 1a or 1b contains only X, we may represent this state by a point on the curve $\alpha = 1$, as for example g, Fig. 3, where the equilibrium pressure is p_X. Similarly, if our system contains only Y we will represent it by a point on $\alpha = 0$, as point e, writing the pressure as p_Y. Now, suppose that in A we have a very dilute solution of X in Y, which for all practical purposes may be considered infinitely dilute. The curve representing this solution will be so close to $\alpha = 0$, Fig. 3, that we shall be unable to distinguish between them. Let us introduce a catalytic agent at b and c, or d, and cause in A an infinitesimal amount, Δx, of dissociation. Suppose we prevent the flow of X across b by pressing piston B against b, while we permit Y to flow into C by reducing slightly the pressure on piston C. The X that is liberated in this process may be allowed to recombine in A; α will increase by $\Delta\alpha$. Experimentally we observe that a state of equilibrium may be reached where there is no flow across c, and where there is a definite pressure difference between A and C. As we continue this process by infinitesimal steps, Δx, we shall have a finite pressure difference $(p_{X \cdot Y} - p_Y)$, which is the osmotic pressure "of X in the solution $(X \cdot Y)$." If we cause a flow from C to A, thus reducing α in A, we find experimentally that the osmotic pressure will also be reduced.

If within C we had a solution of concentration α', and in A one of concentration α'', both at the same temperature, we would observe an osmotic pressure corresponding to the difference in the states f and j, Fig. 3.

Similar considerations will apply to the case where we start with an infinitely dilute solution of Y in X ($\alpha = 1$), and consider the flow of X between A and B. In this case we may start with a constant pressure p_X in B, increase the concentration of Y in A (i.e., reduce α), and arrive at states of equilibrium in A represented by points on the line $ghi \cdots$, Fig. 3. The osmotic pressure "of Y in the solution $(X \cdot Y)$" will be the difference in pressures corresponding to any two points on $ghi \cdots$.

If we start with a finite concentration α in A where the

state is ($p_{X\cdot Y}$, $v_{X\cdot Y}$, α, T), and cause dissociation of $(X \cdot Y)$ into $(X + Y)$ in the constant ratio of $\alpha : (1 - \alpha)$, allowing each product to pass to its respective chamber, or to D, the state in A will be represented by Q (Fig. 3), that in B by g, and that in C by e; for equilibrium, equation (6) will hold. As stated above, this system will be, thermodynamically, analogous to a liquid-vapor system, and we see now that the osmotic pressure of each constituent of the system corresponds to the difference in pressure between that of the total system and the partial pressure of each constituent. We should also note that the osmotic pressure of, say, X in $(X \cdot Y)$ may have different values for the same (T, α), since the dotted line $efj \cdots$, Fig. 3, may be shifted to the right or left as the absolute value of p_Y is changed. Of course, in experimental procedures it has been customary to keep p_Y equal to one atmosphere, which simplifies the results.

The phenomenon of osmosis exhibits an apparent paradox in that the solvent can flow through a semi-permeable membrane from a low to a high pressure. This phenomenon may be explained very simply on the basis of the above considerations. Suppose that Y is the solvent, and at equilibrium we have the state given by (6). Suppose that $p_Y = 1$ atm., and $p_{X\cdot Y} = 100$ atms. at equilibrium. If in Fig. 1 or 1a, the membrane b is replaced by a solid wall, the existence of a partial pressure p_X of 99 atms. could not be observed. Suppose we disturb the equilibrium by reducing $p_{X\cdot Y}$ to, say, 50 atms. Referring to Fig. 3, we transfer our system from Q, along $jfe \cdots$, to a lower pressure where for equilibrium we need a reduced α, or an increase in Y. Therefore, to establish this equilibrium at a lower α, Y will flow from C to A.

IV. SOLUTIONS AS ELECTRIC SYSTEMS.

As we proceed with the study of the system indicated in Fig. 1, particularly when the cylinders contain solutions of different concentrations, it will become obvious to the reader that the system will include a "concentration cell." In calculating the work performed when liquid flows through the semi-permeable membranes, we shall be concerned with electric as well as mechanical work. For this reason, let us consider this phase for a moment.

According to the Debye-Hückel theory of solutions, one liquid, when acting as a solvent for a second liquid, will reduce the electric energy between the molecules of the second liquid. The second will, of course, have the same effect on the first. We may, from this point of view, state that when a solution $(X \cdot Y)$ is formed from $(X + Y)$, electric energy is generated by the system. We shall not go into the microscopic mechanisms of this process, but shall try to draw a few generalizations which will apply to the entire range of concentrations. We need not restrict ourselves to any type of liquid—inorganic or organic, for we must assume that all liquids possess certain electric properties, the difference being only a matter of degree.

Representing the solution as a chemical process, using the form

$$(X + Y) \rightarrow (X \cdot Y),$$

we shall, for purposes of calculation, consider electric energy as being generated by the system when the solution is formed. The process of dilution, i.e.,

$$Y + (X \cdot Y)_{\alpha'} \rightarrow (X \cdot Y)_{\alpha''}$$

will also involve electric work.

Suppose that in A, Fig. 1, we have a solution of concentration α', and in C a solution of concentration α''; we shall prevent any liquid from flowing into B. This will form a concentration cell. If the pistons are made of platinum, say, they may serve as electrodes and we may measure the potential difference for this concentration cell. Experimentally we shall observe that the potential difference will be a function of the concentrations, the temperature, and possibly the pressures on the liquids. If α' in A is held constant, the potential difference will reach a maximum value when $\alpha'' \doteq 0$, i.e., at the same time that the osmotic pressure of X in solution $(X \cdot Y)$ reaches a maximum. Both maxima will, of course, vary with (p_Y, T). If (p_Y, T) is held constant, these maxima will vary with α and $p_{X \cdot Y}$ for A.

As far as this electric system is concerned, we may consider the pure liquid in C at (p_Y, T) to be at a given electrostatic potential, Φ_Y, with respect to some arbitrary standard, say the platinum of the pistons. The solution $(X \cdot Y)$ in A

at $(p_{X\cdot Y}, \alpha, T)$ may be considered at a different electrostatic potential, $\Phi_{X\cdot Y}$, with respect to the same standard. For purposes of mathematical treatment, we may then write, in general,[4] that

$$\Phi_{X\cdot Y} = f_{11}(p_{X\cdot Y}, T, \alpha) = f_{12}(v_{X\cdot Y}, T, \alpha), \qquad (11)$$

where $\Phi_{X\cdot Y}$ is the potential with respect to our arbitrary standard of a solution at a concentration α, temperature T, and pressure $p_{X\cdot Y}$. As $\alpha \doteq 0$, $p_{X\cdot Y} \doteq p_Y$, and $\Phi_{X\cdot Y} \doteq \Phi_Y$, which is the potential for pure Y at (p_Y, T). Similarly, when $\alpha \doteq 1$, $p_{X\cdot Y} \doteq p_X$, and $\Phi_{X\cdot Y} \doteq \Phi_X$, that for pure X at (p_X, T). Referring to Fig. 3, the state of g may now be defined by the coördinates $(p_X, v_X, T, \Phi_X, \alpha = 1)$, e by $(p_Y, v_Y, T, \Phi_Y, \alpha = 0)$, and a solution such as Q by $(p_{X\cdot Y}, v_{X\cdot Y}, T, \Phi_{X\cdot Y}, \alpha)$. For any pressure difference corresponding to any two points on a line, such as $ghi \cdots$, there will be a corresponding e.m.f. and an osmotic pressure.

We may consider $\Phi_{X\cdot Y}$ as a point function [5] within a space occupied by a solution, where $p_{X\cdot Y}$, T and α are functions of the space coördinates and possibly of the time. Differentiating (11), we have

$$d\Phi_{X\cdot Y} = \left(\frac{\partial \Phi_{X\cdot Y}}{\partial p_{X\cdot Y}}\right)_{T,\alpha} dp_{X\cdot Y} + \left(\frac{\partial \Phi_{X\cdot Y}}{\partial T}\right)_{\alpha, p_{X\cdot Y}} dT + \left(\frac{\partial \Phi_{X\cdot Y}}{\partial \alpha}\right)_{p_{X\cdot Y}, T} d\alpha. \qquad (12)$$

Letting r represent a space coördinate, and τ the time, we shall have

$$\left(\frac{\partial \Phi_{X\cdot Y}}{\partial p_{X\cdot Y}}\right)_{T,\alpha} = \left(\frac{\partial \Phi_{X\cdot Y}}{\partial r}\right)_{T,\alpha,\tau} \left(\frac{\partial r}{\partial p_{X\cdot Y}}\right)_{T,\alpha,\tau} + \left(\frac{\partial \Phi_{X\cdot Y}}{\partial \tau}\right)_{T,\alpha,r} \left(\frac{\partial \tau}{\partial p_{X\cdot Y}}\right)_{T,\alpha,r} \qquad (13)$$

and similar relations for $(\partial \Phi_{X\cdot Y}/\partial T)_{\alpha, p_{X\cdot Y}}$ and $(\partial \Phi_{X\cdot Y}/\partial \alpha)_{p_{X\cdot Y}, T}$. From this we see that if within the body of a solution we have a pressure gradient at (T, α) = constant, or a temperature

[4] See article by E. A. Guggenheim, vol. I, *Commentary on the Scientific Writings of J. Willard Gibbs;* particularly § 14.

[5] Not, however, so fine as to consider the atomic and molecular structure.

gradient at $(\alpha, p_{X \cdot Y}) =$ constant, or a concentration gradient at $(p_{X \cdot Y}, T) =$ constant, or if any of these vary with the time, we should expect e.m.f.'s generated within the solution.

E.m.f.'s due to concentration gradients are quite common. However, the effects due to pressure gradient and temperature gradient under their respective constant conditions are not so well known. The theory suggests some very interesting effects. We know that in crystalline solids we observe the effect of piezo-electricity. This has also been observed in non-crystalline solids.[6] This effect is due to the existence of a pressure-gradient within the material; uniform hydrostatic pressure produces no e.m.f.[7] From equation (13) we see that with $(T, \alpha) =$ constant, a case analogous to that of a crystal, we would expect an e.m.f. when a pressure gradient exists, but not when the liquid is at a uniform pressure. Such conditions might be realized when a liquid flows through a narrow constriction. In solids we also have the pyro-electric effect which is due to a temperature gradient within the solid. In metals we have the analogous phenomenon of the Thomson effect in a homogeneous metal, an effect due to a temperature gradient. If such effects exist for liquids, then $(\partial \Phi_{X \cdot Y} / \partial p_{X \cdot Y})_{T, \alpha}$ and $(\partial \Phi_{X \cdot Y} / \partial T)_{\alpha, p_{X \cdot Y}}$ should not vanish. An experimental study of these effects would be very interesting.

Suppose that the cylinders contained their respective liquids as indicated in Fig. 1, and the system were in equilibrium at constant T. If X flowed from B to A, electric work would be produced across a potential difference $\Phi_X - \Phi_{X \cdot Y}$, and mechanical work across the osmotic pressure $-(p_X - p_{X \cdot Y})$. Suppose that α grams of X were thus transferred; the electric energy generated will be

$$W'_X = \alpha \rho_X (\Phi_X - \Phi_{X \cdot Y}), \tag{14}$$

where ρ_X is the electric charge, per unit mass of X. If, at the same time, $(1 - \alpha)$ grams of Y enters A from C, we have for the electric energy generated

$$W'_Y = (1 - \alpha) \rho_Y (\Phi_Y - \Phi_{X \cdot Y}), \tag{15}$$

where ρ_Y is the electric charge per unit mass of Y. The total

[6] *I.C.T.*, vol. VI, p. 208.

[7] Sosman, "The Properties of Silica," 1927; p. 558.

electric energy generated in forming 1 gram of solution will be

$$W' = W'_X + W'_Y = \alpha\rho_X(\Phi_X - \Phi_{X\cdot Y}) + (1 - \alpha)\rho_Y(\Phi_Y - \Phi_{X\cdot Y}). \quad (16)$$

If our system is electrically neutral at the start, and remains so throughout the mixing process, then

$$\alpha\rho_X + (1 - \alpha)\rho_Y = 0. \quad (17)$$

Substituting this in (16), we have

$$W' = \alpha\rho_X(\Phi_X - \Phi_Y) = (1 - \alpha)\rho_Y(\Phi_Y - \Phi_X). \quad (18)$$

Considering the system of Fig. 1 as an electrochemical cell where the terminals are the pistons of B and C, we may write E as the e.m.f. at equilibrium, and place $E = \Phi_X - \Phi_Y$; therefore

$$W' = \alpha\rho_X E. \quad (19)$$

In ordinary cell action, where no attempt is made to adjust the pressures to their equilibrium values, but where they are allowed to be at atmospheric pressure, the osmotic pressures are unbalanced. The flow of solvents due to this unbalance would cause a dissipation in the electric energy. The two effects, the dissipation of mechanical and electric energies, as we see, take place simultaneously.

V. THERMODYNAMICS OF A REVERSIBLE CARNOT CYCLE INVOLVING THE SOLUTION OF TWO LIQUIDS.

In Fig. 4, RW represents the states of $(X \cdot Y)$ and SZ those of $(X + Y)$, both at temperature T_1. As considered above, we may allow a suitable catalytic agent to act for an infinitesimal length of time and cause an infinitesimal fraction, Δx, of $(X \cdot Y)$ to break up into $(X + Y)$ in the ratio $\alpha : (1 - \alpha)$, the necessary energy to be applied from without. We allow the resultant components to pass through their respective membranes. There will be no change in α due to this transfer, and we may adjust $p_{X\cdot Y}$, p_X, p_Y and T to be the same as at the start. This process may be continued by infinitesimal steps until, say, 1 gram of $(X \cdot Y)$ of A has been thus transformed under isothermal-isopiestic-isoplethoric conditions, and may be represented in Fig. 4 by the line RS. This process is, on our assumptions, completely reversible. The latent heat of solu-

tion will be $\lambda'_{p,T,\alpha}$ and we shall consider it as positive when the process $(X \cdot Y) \rightarrow (X + Y)$ is endothermic.

At a different pressure and temperature we shall have a similar process. Consider two such processes at p_1, T_1 and $p_2 = p_1 + \Delta p$, $T_2 = T_1 + \Delta T$, where Δp, ΔT are selected arbitrarily. In Fig. 4 the solid lines are for T_1 and the dotted lines for T_2. The transformation at p_2, T_2 is represented by

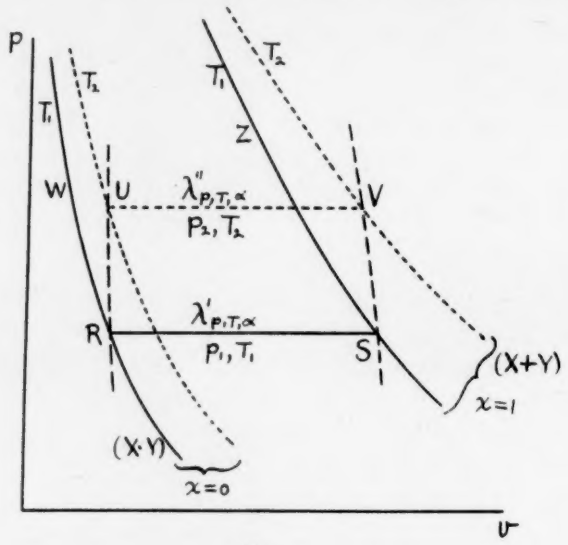

FIG. 4.

UV, where the latent heat is $\lambda''_{p,T,\alpha}$. In general, we shall have

$$\lambda_{p,T,\alpha} = f_{13}(p, T, \alpha) \tag{20}$$

on the assumption that $\lambda_{p,T,\alpha}$ is independent of x, as we actually have in the case of a pure liquid-vapor system. As shown in the previous paper (Apr. 1938, Sections III and IV), we may also write

$$\lambda_{v,T,\alpha} = f_{14}(v, T, \alpha). \tag{21}$$

Write

$$\lambda''_{p,T,\alpha} = \lambda'_{p,T,\alpha} + \Delta\lambda_{p,T,\alpha}.$$

Let us now start with unit mass of $(X \cdot Y)$ at R, and carry it through the closed cycle $RSVU$. We have shown that along RS and VU the process is reversible. Along RU and SV (x, α) = constant, and there is no transfer of material across

the semi-permeable membranes. The only changes involved are those of pressure and temperature; the heat absorbed along SV will be $\kappa_2 \Delta T$, and along RU it will be $-\kappa_1 \Delta T$, where κ_1, κ_2 are the specific heats of $(X \cdot Y)$ and $(X + Y)$ at p, T, α. We shall assume that we may carry our system along SV and UR in a reversible manner, so that the entire cyclic process will be reversible and the resultant change in entropy, say, for such a complete cycle will be zero. Write, then

$$\frac{\lambda'_{p,T,\alpha}}{T_1} + \int_{T_1}^{T_2} \frac{\kappa_2 dT}{T} - \frac{\lambda''_{p,T,\alpha}}{T_2} - \int_{T_1}^{T_2} \frac{\kappa_1 dT}{T} = 0. \qquad (22)$$

Rewriting, we have

$$\frac{\lambda'_{p,T,\alpha} + T_1 \int_{T_1}^{T_2} \frac{\kappa_2 - \kappa_1}{T} dT}{T_1} = \frac{\lambda''_{p,T,\alpha}}{T_2} \qquad (23)$$

and

$$\frac{\lambda''_{p,T,\alpha} - \lambda'_{p,T,\alpha} - T_1 \int_{T_1}^{T_2} \frac{\kappa_2 - \kappa_1}{T} dT}{\lambda''_{p,T,\alpha}} = \frac{T_2 - T_1}{T_2} \qquad (24)$$

or

$$\frac{\Delta\lambda_{p,T,\alpha} - (\kappa_2 - \kappa_1)\Delta T}{\lambda_{p,T,\alpha}} = \frac{\Delta T}{T}. \qquad (25)$$

According to Carnot's theorem, the numerator at the left of (25) represents the total work W derived from this closed cycle, so that

$$W = \Delta\lambda_{p,T,\alpha} - (\kappa_2 - \kappa_1)\Delta T = \frac{\Delta T}{T} \lambda_{p,T,\alpha}. \qquad (26)$$

We must now consider the nature of the work involved in W. It is quite obvious that there is mechanical work, which for the closed cycle $RSVU$ may be written as

$$W'' = (v_2 - v_1)\Delta p = (v_{X+Y} - v_{X \cdot Y})\Delta p. \qquad (27)$$

From Eq. (8) we may write

$$\begin{aligned} \Delta p = \Delta p_{X \cdot Y} &= \Delta p_X + \Delta p_Y \\ &= \left(\frac{\partial p}{\partial T}\right)_{v,x,\alpha} \Delta T + \left(\frac{\partial p}{\partial v}\right)_{x,\alpha,T} \Delta v \\ &\quad + \left(\frac{\partial p}{\partial x}\right)_{\alpha,T,v} \Delta x + \left(\frac{\partial p}{\partial \alpha}\right)_{T,v,x} \Delta\alpha \qquad (28) \end{aligned}$$

and therefore

$$W''' = (v_{X+Y} - v_{X\cdot Y})\left[\left(\frac{\partial p}{\partial T}\right)_{v,x,\alpha}\Delta T + \left(\frac{\partial p}{\partial v}\right)_{x,\alpha,T}\Delta v + \left(\frac{\partial p}{\partial x}\right)_{\alpha,T,v}\Delta x + \left(\frac{\partial p}{\partial \alpha}\right)_{T,v,x}\Delta\alpha\right]. \quad (29)$$

The electric work generated by the system in going from S to R is given by (19). In going from V to U, the electric work will be

$$\alpha\left[\rho_X E + \left(\frac{\partial(\rho_X E)}{\partial T}\right)_p \Delta T + \left(\frac{\partial(\rho_X E)}{\partial p}\right)_T \Delta p\right]. \quad (30)$$

Along the paths SV and UR there is no matter, and therefore no electric charge transferred; no electric work will be involved. The net electric work in going around the complete cycle will be

$$W'' = \alpha\left[\left(\frac{\partial(\rho_X E)}{\partial T}\right)_p \Delta T + \left(\frac{\partial(\rho_X E)}{\partial p}\right)_T \Delta p\right]. \quad (31)$$

Writing $W = W' + W''$, and introducing this into (26), we have

$$\begin{aligned}\lambda_{p,T,\alpha} &= T \lim_{\Delta T \doteq 0}\left\{(v_{X+Y} - v_{X\cdot Y})\left[\left(\frac{\partial p}{\partial T}\right)_{v,x,\alpha} + \left(\frac{\partial p}{\partial v}\right)_{x,\alpha,T}\frac{\Delta v}{\Delta T} + \left(\frac{\partial p}{\partial x}\right)_{\alpha,T,v}\frac{\Delta x}{\Delta T} + \left(\frac{\partial p}{\partial \alpha}\right)_{T,v,x}\frac{\Delta\alpha}{\Delta T}\right] + \alpha\left[\left(\frac{\partial(\rho_X E)}{\partial T}\right)_p + \left(\frac{\partial(\rho_X E)}{\partial p}\right)_T\frac{\Delta p}{\Delta T}\right]\right\} \\ &= T\left\{(v_{X+Y} - v_{X\cdot Y})\left(\frac{\partial p}{\partial T}\right)_{v,x,\alpha} + \alpha\left[\left(\frac{\partial(\rho_X E)}{\partial T}\right)_p + \left(\frac{\partial(\rho_X E)}{\partial p}\right)_T\left(\frac{\partial p}{\partial T}\right)_{v,x,\alpha}\right]\right\}, \quad (32)\end{aligned}$$

since, according to (8), v, T, α and x are independent variables of the system, and in the limit $\Delta v/\Delta T$, etc. will vanish. Intro-

ducing (5) into (32), we have

$$\lambda_{p,T,\alpha} = T\left\{[\alpha v_X + (1-\alpha)v_Y - v_{X\cdot Y}]\left(\frac{\partial p}{\partial T}\right)_{v,x,\alpha} + \alpha\left[\left(\frac{\partial(\rho_X E)}{\partial T}\right)_p + \left(\frac{\partial(\rho_X E)}{\partial p}\right)_T\left(\frac{\partial p}{\partial T}\right)_{v,x,\alpha}\right]\right\}. \quad (33)$$

It is interesting to note here the similarity of Eq. (32) with that of the Clapeyron-Clausius equation. The difference between these equations is that in the present case we have the electrical terms. We should, theoretically, have included electric work in addition to mechanical work, in deriving the Clapeyron-Clausius equation, and then the two equations would have been identical. The question arises—does an equation of the type of (11) apply to a liquid-vapor system of a chemically pure material? It would appear from our experience with such systems that $\Phi = 0$ for such systems. Can we say, from a thermodynamic analogy of a liquid-vapor system with that of a solution as we discussed above, that the former is a limiting case of liquid-vapor systems which are mixtures of two components and write that $\Phi_{X\cdot Y} - \Phi_Y \doteq 0$ as $\alpha \doteq 0$? Another view which we may take is that for a chemically pure material, the value for E between the liquid and its vapor is very small; however, might not $\rho_X E$ have an appreciable value? If these points have received experimental study, the writer is not aware of it.

The partial latent heat of solution at p, T = constant will be given by

$$\left(\frac{\partial\lambda_{p,T,\alpha}}{\partial\alpha}\right)_{p,T} = T\left\{\left[v_X - v_Y - \left(\frac{\partial v_{X\cdot Y}}{\partial\alpha}\right)_{p,T}\right] \times \left(\frac{\partial p}{\partial T}\right)_{v,x,\alpha} + \left[\left(\frac{\partial(\rho_X E)}{\partial T}\right)_p + \left(\frac{\partial(\rho_X)E}{\partial p}\right)_T\left(\frac{\partial p}{\partial T}\right)_{v,x,\alpha}\right]\right\} + T[\alpha v_X + (1-\alpha)v_Y - v_{X\cdot Y}]\left[\frac{\partial}{\partial\alpha}\left(\frac{\partial p}{\partial T}\right)_{v,x,\alpha}\right]_{p,T} + T\alpha\left\{\frac{\partial}{\partial\alpha}\left[\left(\frac{\partial(\rho_X E)}{\partial T}\right)_p + \left(\frac{\partial(\rho_X E)}{\partial p}\right)_T\left(\frac{\partial p}{\partial T}\right)_{v,x,\alpha}\right]\right\}_{p,T}. \quad (34)$$

In the limiting case, when $\alpha \doteq 0$, $v_{X \cdot Y} \doteq v_Y$, and we will have

$$\lim_{\alpha \doteq 0} \left(\frac{\partial \lambda_{p,T,\alpha}}{\partial \alpha} \right)_{p,T} = T \left\{ \left[v_X - v_Y - \left(\frac{\partial v_{X \cdot Y}}{\partial \alpha} \right)_{p,T} \right] \times \left(\frac{\partial p}{\partial T} \right)_{v,x,\alpha} + \left[\left(\frac{\partial (\rho_X E)}{\partial T} \right)_p + \left(\frac{\partial (\rho_X E)}{\partial p} \right)_T \left(\frac{\partial p}{\partial T} \right)_{v,x,\alpha} \right] \right\}. \quad (35)$$

We may write (33) and (35) in terms of molal quantities, as follows: Let

M_X = molecular weight of X,
M_Y = molecular weight of Y,
n_X = no. mols. of X in the entire system,
n_Y = no. mols. of Y in the entire system.

Then

$$\alpha = \frac{n_X M_X}{n_X M_X + n_Y M_Y}. \quad (36)$$

For a system whose total mass is $(n_X M_X + n_Y M_Y)$ the latent heat of solution will be

$$\begin{aligned} \Lambda_{p,T,\alpha} &= (n_X M_X + n_Y M_Y) \lambda_{p,T,\alpha} \\ &= T \left\{ \left[n_X M_X v_X + n_Y M_Y v_Y - (n_X M_X + n_Y M_Y) v_{X \cdot Y} \right] \left(\frac{\partial p}{\partial T} \right)_{v,x,\alpha} \right. \\ &\quad \left. + n_X M_X \left[\left(\frac{\partial (\rho_X E)}{\partial T} \right)_p + \left(\frac{\partial (\rho_X E)}{\partial p} \right)_T \left(\frac{\partial p}{\partial T} \right)_{v,x,\alpha} \right] \right\}. \quad (37) \end{aligned}$$

If we write $V_X = M_X v_X$, $V_Y = M_Y v_Y$,

$$V_{X \cdot Y} = \frac{n_X M_X + n_Y M_Y}{n_X + n_Y} v_{X \cdot Y},$$

and $P_X = M_X \rho_X$, then (37) becomes

$$\Lambda_{p,T,\alpha} = T\left\{ [n_X V_X + n_Y V_Y - (n_X + n_Y) V_{X \cdot Y}] \times \left(\frac{\partial p}{\partial T}\right)_{v,x,\alpha} + n_X \left[\left(\frac{\partial (P_X E)}{\partial T}\right)_p + \left(\frac{\partial (P_X E)}{\partial p}\right)_T \left(\frac{\partial p}{\partial T}\right)_{v,x,\alpha} \right] \right\}. \quad (38)$$

and the partial molal latent heat, from (38) will be

$$\left(\frac{\partial \Lambda_{p,T,\alpha}}{\partial n_X}\right)_{p,T} = T\left\{ \left[V_X - V_{X \cdot Y} - (n_X + n_Y) \times \left(\frac{\partial V_{X \cdot Y}}{\partial n_X}\right)_{p,T} \right] \left(\frac{\partial p}{\partial T}\right)_{v,x,\alpha} + \left[\left(\frac{\partial (P_X E)}{\partial T}\right)_p + \left(\frac{\partial (P_X E)}{\partial p}\right)_T \left(\frac{\partial p}{\partial T}\right)_{v,x,\alpha} \right] \right\}$$
$$+ T\left\{ [n_X V_X + n_Y V_Y - (n_X + n_Y) V_{X \cdot Y}] \times \frac{\partial}{\partial n_X} \left(\frac{\partial p}{\partial T}\right)_{v,x,\alpha} + n_X \frac{\partial}{\partial n_X} \left[\left(\frac{\partial (P_X E)}{\partial T}\right)_p + \left(\frac{\partial (P_X E)}{\partial p}\right)_T \left(\frac{\partial p}{\partial T}\right)_{v,x,\alpha} \right] \right\}. \quad (39)$$

In the limiting case, when $n_X \doteq 0$, $V_{X \cdot Y} \doteq V_Y$, then (39) becomes

$$\lim_{n_X = 0} \left(\frac{\partial \Lambda_{p,T,\alpha}}{\partial n_X}\right)_{p,T} = T\left\{ \left[V_X - V_Y - n_Y \left(\frac{\partial V_{X \cdot Y}}{\partial n_X}\right)_{p,T} \right] \left(\frac{\partial p}{\partial T}\right)_{v,x,\alpha} + \left[\left(\frac{\partial (P_X E)}{\partial T}\right)_p + \left(\frac{\partial (P_X E)}{\partial p}\right)_T \left(\frac{\partial p}{\partial T}\right)_{v,x,\alpha} \right] \right\}. \quad (40)$$

VI. CONCLUDING REMARKS.

This problem was approached from a phenomenological standpoint. Very little use was made of atomic theory. The concepts and use that were made of catalytic agents, are,

from the writer's point of view, justified by recent studies on chain reactions. As was pointed out by the writer in a previous paper, the reason why a reaction is termed "spontaneous," is because we do not know the catalytic agent which controls the process. With this knowledge, we should be able to carry out the reaction in an orderly and reversible manner.

The writer has avoided completely the use of "perfect" liquids in this paper, just as he had eliminated the use of "perfect" gas in his previous paper. In both cases, the state of being "perfect" is obviously artificial.

SUMMARY.

This paper is an extension of the thermodynamic studies made by the writer on a single gaseous phase and liquid-vapor systems. Including catalysis in our basic thermodynamic considerations, the writer shows that the process of mixing two chemically pure liquids to form a solution is thermodynamically analogous to the evaporation of a liquid. Osmotic pressure is shown to be analogous to vapor pressure, and the interrelations between osmotic pressure and the e.m.f. of a concentration cell are developed. Finally, a mathematical relation is developed between the latent heat of solution, the specific volumes of the individual liquids and that of the solution, the concentration of the solution, the e.m.f. and electric charge of the concentration system.

The entire treatment applies to concentrations ranging from 0 to 100 per cent. of each component.

NOTES FROM THE NATIONAL BUREAU OF STANDARDS.*

A DOMESTIC SUPPLY OF FLAX AND LINEN.

The present difficulty in obtaining normal supplies of flax and linen from Europe has renewed interest in the possibility of developing a domestic source of this valuable fiber. The Textile Foundation in cooperation with the Bureau has completed a preliminary survey of the present situation. This included interviews with those in charge of the experiments being conducted by the Tennessee Valley Authority and the Georgia School of Technology, with several paper manufacturers, with spinners and weavers of linen in New England, and with those who are growing flax and preparing fiber in Oregon.

The United States now produces about half the amount of fiber needed for coarse linen goods. Increased production seems to be largely a matter of economics, although the need for certain technical improvements is obvious.

No fiber of the quality required for fine linen goods has ever been produced in this country. To accomplish this would necessitate the development of an entirely new industry based upon individual craftsmanship rather than mass-production. It would, therefore, appeal but little to American psychology.

The survey shows that additional information is needed about the structure and composition of the flax fiber, and about the mechanism of present methods of preparation. The complete report of this work will be published in pamphlet form by the Textile Foundation.

ADHESIVE STRENGTH OF GUMMED PAPER SEALING TAPE.

The evaluation of the gummed paper tape used so widely for sealing fiber shipping containers will be on a utilitarian basis only if the strength of the seal it will form is predicted. The strength of the ultimate seal will depend on two factors:

* Communicated by the Director.

the strength of the paper tape itself and the strength of the bond which the adhesive forms between the carton and the paper tape. The first factor is readily determined by the conventional strength tests applied to paper, but until recently no satisfactory measure of adhesion could be obtained. However, a method of determining this factor has now been developed commercially and has met the requirements set up by the Bureau in connection with the preparation of a Federal specification.

The new test, which combines a hand-operated tape moistener with a motor-driven, electrically timed and synchronized apparatus for affixing the tape with controlled pressure to a standard test paper, measures the force required to break the seal after a definite setting period. The test seal is slipped apart by applying the force in a manner that simulates the stress exerted by the flaps of a fiber box on the seal which holds them in place. The apparatus is known as the Harnden-McLaurin Gummed Tape Tester.

FIBER TILE BOARDS.

Fiber tile boards, a relatively new type of interior finishing material, have been tested at the Bureau to determine their probable lasting quality. This material which is suitable for a variety of uses, appears to have a place in low cost house construction because of its relative cheapness and ease of installation. The tile boards consist of a vegetable-fiber board in large sheets having on one side a dense, hard coating which is scored to resemble ceramic tile.

The boards were subjected to cycles of steaming and drying and were tested for density, expansivity, flexural properties, resistance to household cleaners, staining, and resistance of the finish to impact. They were subjected to conditions more drastic than would ordinarily be encountered in service to produce in a relatively short time results that would be likely to arise from long periods of service.

In general, the fiber tile showed good resistance to staining, to abrasive cleaning powders, and impact. However, the surface coatings were in most instances damaged by the cycles of steaming and drying, especially at the edges and in some

instances at the score marks where the moisture had access to the base material. The results obtained indicate the importance of protecting the edges of the material as installed, and the value of a sufficiently thick coating over the entire surface, including the score markings.

FLUIDITIES OF CELLULOSE DISPERSIONS.

The fluid properties of solutions of cellulose textile fibers, such as cotton or rayon, are characteristic of the extent to which the cellulose has been degraded, for example, by bleaching, acids, alkalies, light, or mildew. Fluidity measurements are sensitive means for indicating the degree of degradation. These measurements have been commonly made with cuprammonium solution which, however, decomposes in contact with air, and requires special conditions for storage and handling. The cuprammonium solution is considered by some to be difficult to prepare.

The possibility of using dimethyldibenzylammonium hydroxide (commercially called Triton F) and sodium hydroxide solution containing carbon disulfide, in place of the usual cuprammonium solution, was investigated at the Bureau by the research associates of the Textile Foundation. Fluidity measurements were made on muslin, using each of the three solvents on samples treated with acid of different concentrations, and samples bleached with chlorine for different lengths of time.

The results of the tests, which are given in RP1441 by Ralph T. Mease and L. F. Glaysteen in the December *Journal of Research*, showed that the fluidity of the cellulose in any of the solvents could be used for indicating the state of degradation. However, where celluloses representing a wide range of fluidities are to be tested, the cuprammonium solution is to be preferred. Celluloses of little or no degradation dissolve more readily in cuprammonium than in either Triton F or a mixture of carbon disulfide and sodium hydroxide. The results of the tests described in RP1441 show the relation between the fluidities of the cellulose in the different solvents with regard to degradation produced by acid hydrolysis and chlorine bleach, and measured by tests of breaking strength.

DISSOLVING CELLULOSE IN CUPRAMMONIUM.

Certain flow properties of solutions of cellulose textile fibers are related to the degree of degradation of the cellulose. In order to measure flow characteristics, it has been the practice to form the solution in the viscometer by placing the fibers in it together with cuprammonium solution, and a steel plunger to furnish mechanical agitation as the viscometer is tilted end over end. This required a separate viscometer for each determination. The viscometers were subjected to considerable wear, which often resulted in breakage. Solution of the cellulose was not always complete. Occasionally fibers were forced into the capillary of the viscometer with consequent loss of the measurement.

A simplified method for preparing the cellulose solutions has been developed at the Bureau which overcomes these disadvantages. It is described in a paper by Ralph T. Mease (RP1442) in the December *Journal of Research*. Mixing vials with glass plungers instead of the more expensive viscometers are used. The viscometers, therefore, can be reserved for flow measurements only. The wear on the viscometers and their number are thus considerably reduced. The cellulose solutions are transferred from the mixing vial to the viscometer for flow measurements. Data presented show that the exposure of the solution to the air for the short time required to pour it into the viscometer has no measurable effect on the fluidity.

CHLORITES FOR TREATING RAW SUGARS.

The use of sodium and calcium chlorites for bleaching sugar solutions has been investigated by Horace S. Isbell, and a method for treating raw sugar is described in the *Journal of Research* for December (RP1436). Chlorites in neutral and slightly acid solutions exert bleaching action on the colored impurities in raw sugar. In addition to the bleaching effect, chlorites have marked bactericidal properties, so that treatment of raw sugars and sugar solutions with chlorites inhibits bacterial action. Ordinarily, considerable time elapses between the production of raw sugar and its use at the refinery, and during this period there is loss of sucrose by bacterial action. Since pure sucrose is not altered by contact with

chlorites for long periods of time, the chlorite can remain in contact with the sugar crystals in storage and thus act as a preservative. In the technological application of the process the raw sugar might be merely sprayed in the centrifugal with a solution containing the chlorite; then the small quantity of chlorite solution remaining with the sugar crystals would exert the desired bleaching and preserving effects. The cost of the treatment, which would depend almost entirely on the cost of chlorite, should not be excessive because chlorites are now being produced in commercial quantities for use in the textile and paper industries.

ISOMERIZATION OF PARAFFIN HYDROCARBONS.

In recent years, the petroleum industry has developed (for use on a commercial scale) catalysts that will isomerize paraffin hydrocarbons. It is desired to convert, as far as possible, a given lot of paraffin hydrocarbons (as from an appropriate fraction of petroleum) into those isomers that will in themselves have the least tendency to knock when used as fuel in automotive engines, or into those isomers (as n-butane into isobutane) which may be used as one of the reactants in a process (as the addition of ethylene to isobutane) to form fuel having little tendency to detonate in an engine. Therefore, it is desirable to know the temperatures at which, with the proper catalyst, optimum concentrations of the possible desired isomers may be formed.

In RP1440 in the *Journal of Research* for December, Frederick D. Rossini and Edward J. R. Prosen of the Bureau, with Kenneth S. Pitzer of the University of California, present in tabular and graphical form for the two butanes, the three pentanes, the five hexanes, and the nine heptanes (all in the ideal gaseous state), for the range 298° to 1000° K., values of the following thermodynamic properties: (*a*) the standard free energy of isomerization divided by the absolute temperature, $\Delta F^\circ/T$; and (*b*) the relative amounts of the several isomers present at equilibrium with each other. Comparison is made of these calculated values of the equilibrium concentrations with the directly-measured values reported by other investigators for equilibria involving (*a*) the two butanes, (*b*) two pentanes, and (*c*) four hexanes.

EFFECT OF CALCIUM CHLORIDE ON STRENGTH OF CONCRETE AT LOW TEMPERATURES.

The problem of concreting in freezing weather arises frequently in many parts of the United States. It is well known that the value of concrete if "frozen" may be utterly destroyed as a structural material. Consequently, present day methods prescribe that if concrete is placed in freezing weather, it will be heated and maintained by heaters and insulating materials, at temperatures well above the freezing point.

The use of calcium chloride has been suggested in addition to the foregoing precautions, as it speeds the attainment of strength and consequently reduces the time during which protection is necessary.

Since the addition of a small amount of calcium chloride reduces the freezing point of water by only a few degrees, it has been assumed that calcium chloride would not prevent the freezing and destruction of concrete which is cooled well below the freezing point.

In order to study the effect of low storage temperatures on concrete, Jason C. Yates, research associate of the Calcium Chloride Association at the Bureau made specimens of concrete at 70° F. and containing 0, 2, 3, and 4 per cent. of calcium chloride by weight of cement, and immediately placed them in rooms kept at various temperatures between 20° and 40° F.

The specimens were maintained at these storage temperatures until one day before testing, when they were removed. It was found that, with the exception of the plain concrete stored at 20° F., all the specimens gained strength. At 28 days the plain concrete at 25° F. had a strength of 1,130 lb./in.^{2} at 32° F. a strength of 3,150 and at 40° F. a strength of 3,790 lb./in.^{2}.

The addition of calcium chloride increased the strengths at all temperatures and at all ages. The earlier the age, and the lower the temperature, the greater the effect of the calcium chloride. With 4 per cent. of calcium chloride, the 28-day strength at 20° F. was 1,370 lb./in.^{2}; at 25° F. it increased the strength from 1,130 up to 3,030 lb./in.^{2}.

HIGH-TEMPERATURE FURNACE.

The manufacture of modern ceramic specialties such as sparkplug insulators has involved the use of higher and higher temperatures. While a proposal 25 years ago to mature ware at 1,500° C. (2,732° F.) would have been considered revolutionary, the industry today is using temperatures approaching 1,800° C. (3,272° F.) and is not hesitating to consider the eventuality of much higher heat treatments.

Such plans necessarily involve, first of all, laboratory equipment in which exploratory tests can be made under conditions simulating those desired in industrial furnaces. Up to the present, heating preformed specimens to temperatures above the upper limit of conventional "platinum-wound" furnaces (about 1,600° C.) (2,912° F.) has, with rare exceptions involved reducing or, at best, neutral conditions. A paper by R. F. Geller in the December *Journal of Research* (RP1443) deals with the design of, and the results of preliminary tests with, a furnace in which specimens have been heated under oxidizing conditions in the range from 1,800° to 2,000° C. (3,272° to 3,632° F.). The heat is derived from electrical resistors of the Nerst filament type. The results of some preliminary tests may be summarized as follows:

Shapes (*a*) of magnesia and of thoria, (*b*) of beryllia and of thoria, and (*c*) of zirconia and of thoria were heated in mutual contact at temperatures as high as 2,000° C. without harmful effects.

No interaction occurred when (*a*) shapes of alumina and of thoria were heated in contact at 1,850° C. (3,362° F.), (*b*) shapes of alumina and of zirconia were heated under the same conditions of 1,900° C. and (*c*) shapes of magnesia and of beryllia, and of alumina and of beryllia were heated in contact at 1,800° C. and at 1,825° C. (3,272° and 3,317° F.) respectively. Considerable fusion did occur when the combinations in question were heated at temperatures approximately 50° C. above those mentioned.

When an intimate mixture of zirconia and thoria in equimolecular ratio was heated at approximately 2,000° C. (3,632° F.) the product has an anomalous thermal expansion, showing a large reversal between approximately 500° and 1,000° C. (932° and 1,832° F.) during both heating and cool-

ing. This is in sharp contrast to the regular expansion of either thoria or zirconia after having been heated alone to 2,000° C. (3,632° F.), and cannot be explained by the formation of a compound since the X-ray patterns and petrographic examination show only the presence of the original oxides.

When an intimate mixture of magnesia and alumina in 1 : 1 mole ratio was heated at approximately 2,000° C. (3,632° F.), the principal product was spinel.

When intimate mixtures of alumina and beryllia in 1 : 1 mole ratio were heated at from 1,800° C. to 1,880° C. (3,272° to 3,416° F.) the principal product, as shown by diffraction patterns, was chrysoberyl. This compound fused between 1,855° C. and 1,880° C. (3,371° and 3,416° F.).

ELECTROMOTIVE FORCE OF STANDARD CELLS CONTAINING DEUTERIUM OXIDE.

Millions of volts or a millionth of a volt are within the range of modern electrical measurements, but the first is a trillion times larger than the latter. The same unit, the volt, serves for both and the standard is the Weston normal cell. Actually, a selected group of these cells at the Bureau serves as the primary standard for the volt in the United States, and much care is devoted to its preservation. The constancy of the cells is most important. Fortunately there are several ways by which this can be judged, and these are concordant in showing that the unit today is the same as it was thirty years ago to within one part in 100,000. It is important, nevertheless, that new and better types of standard cells should be developed. For this reason, L. H. Brickwedde and G. W. Vinal have made a study of the possibility of constructing cells with the so-called heavy water (deuterium oxide) in place of the ordinary water. This research, extending over a period of several years, has shown that a new type of cell having excellent possibilities as a standard can be made by using high percentages of heavy water. These cells are remarkably constant during the early part of their service life when the ordinary type of cell is subject to fluctuations before attaining its equilibrium value.

PRESENT STATUS OF CATHODIC PROTECTION OF PIPE LINES.

The use of an external current applied cathodically for protecting pipe lines against corrosion was first undertaken about 1910 or earlier. Since that time this system of protection has been widely extended, especially within the last 10 years. According to a recent estimate, 750 cathodic protection units, protecting 3000 miles of line, are in operation. Because of the practical importance of cathodic protection, K. H. Logan of the Bureau's Underground Corrosion Section held a number of conferences on this subject with pipe-line operators and corrosion engineers during the summer of 1941. These all indicated that cathodic protection is both practical and economical for the protection of transmission pipe lines. It has even proved successful in protecting distribution systems in the few cities in which the method has been tried. Because of interlacing networks, the difficulties in protecting distribution systems are, of course, much greater.

Such failures in the operation of cathodic protection as have been reported are to be attributed to poor design and poor maintenance, and since similar failures are to be expected in any pioneering undertaking, they are not to be taken too seriously. One of the major unsolved problems in cathodic protection is the measurement of the minimum current density required for protection. Otherwise, it is difficult to determine, except by experience, whether a pipe line is over or under protected.

Ultraviolet Lamps Used in Production of Beer.—(*Refrigerating Engineering*, Vol. 42, No. 4.) The first complete application of ultraviolet lamps to safeguard the production of beer has been made at the Duquesne Brewing Company, Pittsburgh, Pa. The various ingredients going to make up beer are first boiled in a vat after which it is called wort. This is cooled from about 200 deg. F. down to 50 deg. by passing the liquid over cooled copper pipes through which a refrigerant is circulated. During this process, the wort may be exposed to wild yeast spores floating in the air which can be effectively removed by ultraviolet irradiations. If these yeast spores were not eliminated, secondary fermentations might be set up affecting the flavor uniformity of the brew and, in severe cases, might cause complete spoilage. After cooling, the wort is piped to fermenting tanks where it remains until fermentation is completed. The liquid is then drawn off into aging vats and is finally bottled. A portable unit consisting of six 30 in. Sterilamps is inserted in an opening at the side of the fermenting tank and is permitted to burn until enough cooled wort is available to fill the tank. This insures elimination of practically all microörganisms in the air and on the inside surface of the tanks. The minimum radiation time is about one-half hour but may run as high as several hours. In the bottling department a conveyor carries the bottles from the soaker (water and sterilizing machine) to the filling and capping machines. Over the top as close as possible to the open ends of the bottles, is mounted an inverted U-shaped hood of stainless steel. Continuous line of Sterilamps under the hood prevents any air-borne bacteria from contaminating the bottles before they are filled. The hood, in addition to shielding the eyes of the workmen from direct radiation, also prevents dirt from getting into the bottles as they pass to the automatic filling machine.

R. H. O.

THE FRANKLIN INSTITUTE.

STATED MONTHLY MEETING, DECEMBER 17, 1941.

The regular monthly meeting of The Franklin Institute was called to order at 8:15 P.M. by Mr. Charles S. Redding, newly elected President of The Franklin Institute.

Upon motion, the minutes of the November meeting were duly approved as printed in the December issue of the JOURNAL.

The Chair then called upon the Secretary of the Institute, Dr. Henry Butler Allen, for his report. Dr. Allen stated that since the last meeting the following additions in membership had taken place:

Active	20
Associate	6
Student	165
Total	191

Dr. Allen then announced that in accordance with the By-Laws of The Franklin Institute, Article IV, Section 4, nominations for officers and a portion of the number of Board of Managers members should be acted upon at this, the December monthly meeting of the Institute.

He stated that in compliance with regulations, the following names were submitted to the members:

President
(to serve one year).
Charles S. Redding

Vice-Presidents
(to serve one year).
Walton Forstall
W. Chattin Wetherill
Samuel S. Fels
Richard W. Lloyd
Richard T. Nalle

Treasurer
(to serve one year).
M. M. Price

Members of the Board of Managers
(to serve three years).
Edward G. Budd
Clarence A. Hall
A. Atwater Kent
William F. Kurtz
Orus J. Matthews
George W. Pepper
James S. Rogers

(to serve two years).
Philip C. Staples

There being no other names submitted, upon motion, duly seconded and carried, the nominations were declared closed.

The presiding officer then introduced the speaker of the evening, Dr. C. E. K. Mees, Director of Research and Development, Eastman Kodak Company, who spoke on "Direct Processes for Making Photographic Prints in Color."

Dr. Mees, for the first time in public, spoke of the progress which has been made toward meeting the great demand for photographic prints in color. He pointed out that high quality was essential and that the cost would have to be reasonable. He then spoke at length, not only of the work accomplished along these lines but of the work for the future which promises to be of value.

The meeting adjourned with a rising vote of thanks to the lecturer.

HENRY BUTLER ALLEN,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of Stated Meeting held Wednesdar, December 10, 1941)

HALL OF THE COMMITTEE,
PHILADELPHIA, DECEMBER 10, 1941.

MR. COLEMAN SELLERS, 3RD, *in the Chair.*

The following reports were presented for final action:

No. 3089: Safety Inner Tube for Pneumatic Tires.

This report recommended the award of a Certificate of Merit to The Goodyear Tire and Rubber Company, of Akron, Ohio, "In consideration of the development and successful manufacture of a safety tire which lessens the risk of damage to life and property caused by tire blowouts."

No. 3094: Work of Claude S. Hudson.

This report recommended the award of an Elliott Cresson Medal to Claude Silbert Hudson, of Washington, D. C., "In consideration of his distinguished investigations in carbohydrate chemistry, which have greatly enriched our knowledge of this field and stimulated the work of other investigators through the formulation of general principles and the development of new and improved experimental procedures."

JOHN FRAZER,
Secretary to Committee.

LIBRARY NOTES.

Photostat Service. Photostat prints of any material in the collections can be supplied on request. Orders received in the morning are filled the same day. The average cost for a print 9 × 14 inches is thirty-five cents.

The library and reading room are open on Mondays, Tuesdays, Fridays and Saturdays from nine o'clock A.M. until five o'clock P.M., Wednesdays and Thursdays from two until ten o'clock P.M.

RECENT ADDITIONS.

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ANDERSON, NEWTON H. Aircraft Layout and Detail Design. First Edition. 1941.

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BROOKS, ELBRIDGE S. The True Story of Franklin. 1940.
SEABROOK, WILLIAM. Doctor Wood. 1941.

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WAISMAN, HARRY A., AND C. A. ELVEHJEM. The Vitamin Content of Meat. 1941.

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American Association of Cereal Chemists. Committee on Revision. Cereal Laboratory Methods. Fourth Edition. 1941.
American Public Health Association and Association of Official Agricultural Chemists. Standard Methods for the Examination of Dairy Products. Eighth Edition. 1941.
HASSLER, JOHN W. Active Carbon the Modern Purifier. 1941.
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NOYES, WILLIAM ALBERT, JR., AND PHILIP ALBERT LEIGHTON. The Photochemistry of Gases. 1941.
PERRY, JOHN H., Editor. Chemical Engineers' Handbook. Second Edition. 1941.
YOE, JOHN H., AND LANDON A. SARVER. Organic Analytical Reagents. 1941.
ZECHMEISTER, L., AND L. CHOLNOKY. Principles and Practice of Chromatography. 1941.

ELECTRICITY AND ELECTRICAL ENGINEERING.

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KELLY, HARRY C. A Textbook in Electricity and Magnetism. 1941.
REICH, HERBERT J. Principles of Electron Tubes. First Edition. 1941.
WHITEHORNE, EARL. Electrical Wiring Specifications. First Edition. 1941.

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MANUFACTURES.

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HANSEN, EMIL M. Modern Marine Pipefitting. 1941.
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COLE, CHARLES BRADFORD. Tool Design. 1941.
HETZEL, FREDERIC V., AND RUSSELL K. ALBRIGHT. Belt Conveyors and Belt Elevators. Third Edition, Revised and Enlarged. 1941.

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DOAN, GILBERT E., AND ELBERT M. MAHLA. The Principles of Physical Metallurgy. Second Edition. 1941.
Yale Metallurgical Alumni. Champion Herbert Mathewson. Sixtieth Birthday. 1941.

METEOROLOGY.

MIDDLETON, W. E. KNOWLES. Meteorological Instruments. 1941.

PHARMACY AND HYGIENE.

GOODMAN, LOUIS, AND ALFRED GILMAN. The Pharmacological Basis of Therapeutics. 1941.
GRAY, GEORGE W. The Advancing Front of Medicine. 1941.

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Modern Photography, 1941–1942.
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BROWNE, C. A., AND F. W. ZERBAN. Physical and Chemical Methods of Sugar Analysis. Third Edition. Rewritten and Reset. 1941.

NOTES FROM THE BARTOL RESEARCH FOUNDATION.

FURTHER CONFIRMATION OF THE MONTGOMERY THEORY OF COUNTER DISCHARGE.*

BY

W. E. RAMSEY AND WAYNE L. LEES.

The Montgomery theory[1] of counter discharge makes it possible to predict the dependence of pulse size (maximum negative potential change of the counter wire) upon wire capacity and counter length under conditions where it is safe to assume that the discharge starts simultaneously at all points in the tube. The picture is particularly interesting if, as we vary counter length and wire capacity, the discharge passes from what has been termed a "slow" breakdown to a "fast" breakdown (for non-self-quenching gas mixtures). It follows from the discharge mechanism that for a given cylinder potential and wire capacity there is a length l_e such that for all $l \leqslant l_e$ the pulse size is constant and equal to the over-voltage on the counter. For values of $l > l_e$, $V = l\alpha/C$, where α is the charge per unit length in the positive ion sheath necessary to quench the discharge at the assigned cylinder potential. For $l < l_e$ the counter is breaking multiply in each discharge and the succession of these multiple breaks produces what has been called a slow breakdown. For $l < l_e$ the counter is "over-shooting." Here there is only one break in the discharge and the counter has been referred to as having a fast breakdown.

If the discharge does not start at all points in the tube within a short time interval (10^{-7} second) after it has started at one point, the linear charge density will not be constant over the counter length and the picture, although unaltered in form, is modified somewhat in detail to allow for the finite time required for the discharge to propagate itself from one

* Reprinted from *The Physical Review*, **60**, 411 (1941).

[1] C. G. Montgomery and D. D. Montgomery, *Phys. Rev.*, **57**, 1030 (1940).

point to another. Simple considerations combined with direct observations on the time variation of counter wire potential[2] indicate that this time of propagation is only important in modifying the picture for small C and large l.

Figure 1 is a family of curves showing the variation of

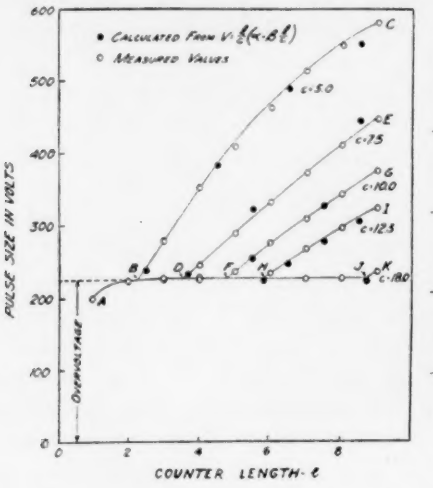

FIG. 1. FIG. 2.

FIG. 1. Maximum potential change of counter wire and its variation with counter length for a series of wire capacities. C expressed in farads in the empirical expression, $\alpha = 5.2 \times 10^{-10}$, $\beta = 1.2 \times 10^{-22}$. Low value of A due to end effect in short counter.

FIG. 2. Counter cylinder composed of nine separately insulated segments. The number of segments above (here 225 volts above) starting potential defines the effective counter length, other segments being at a value below the starting potential. Thus by changing the potential of the segments the effective counter length may be changed *without altering capacity of the wire system.* Capacity changes were made by adding condensers between wire and ground. Voltage swing measured using a weakly coupled electrometer tube and grounding counter wire with key after each discharge. Counter filled with 9 cm. argon-oxygen mixture.

pulse size with l for a series of values of C. Here great care was taken in the experimental procedure to obtain low values of C, *variation of l without altering C*, and a true value of the

[2] W. E. Ramsey, *Phys. Rev.*, **57**, 1022 (1940).

maximum negative voltage when no charge is allowed to leak from the counter wire. Refer to Fig. 2 and its caption for a description of the procedure.

In Fig. 1, ABC is the characteristic for $C = 5.0\mu\mu f$, ADE for the wire capacity C equal to $7.5\mu\mu f$, AFG for $C = 10.0\mu\mu f$, and so on. Examination of this family reveals that the lengths AB, AD, AF, AH, AJ (values of l_e) are proportional to C. The family may be represented satisfactorily by the relation V = Constant = over-voltage for values of $l \leqslant l_e$ and $V = (l/C)[\alpha - \beta(l/C)]$ for values of $l \geqslant l_e$. Here α is the constant charge per unit length referred to above and experimentally obtained for small l and large C. Thus to a first approximation propagation time reduces the average charge per unit length by an amount proportional to l/C.

The experimental picture obtained agrees with the picture presented by the theory, altered only to allow for propagation times of the order of 10^{-7} second. The authors have been unable to reconcile the results obtained with any picture of the discharge differing materially from that presented by this theory.

NOTES FROM THE BIOCHEMICAL RESEARCH FOUNDATION.

The Effect of Tumor Implantation on the Estrous Cycle of Rats.—J. O. ELY AND R. L. PHILLIPS. Several investigators have reported a relationship between the estrous cycle in mice and rats and spontaneous tumors of the genital organs and the mammary glands. Allen, Diddle, Strong, Burford and Gardner (*American Journal of Cancer*, **25**: 291, 1935) found that with advanced growth of spontaneous tumors (in mice) the estrous cycles became infrequent and long-continued periods of diestrus occurred. Lacassagne (*Compt. rend. soc. Biol.*, **114**: 427, 1933) reported the production of mammary tumors in mice by the injections of folliculin over long periods of time. Wolfe, Burack and Wright (*American Journal of Cancer*, **38**: 383, 1940) found that with the Albany strain of rats no particular type of estrous history could be correlated definitely with the appearance of spontaneous tumors. However, when the estrous histories of large groups of these rats were studied, small but significant quantitative differences were evident between the histories of rats with tumors and those without tumors. Other investigators have studied the influence of transplanted tumors on the estrous cycle in rats and mice. Pribram (*Zeitschrift für Krebsforschung*, **25**: 336, 1932) found that tumor implantation terminated the estrous cycle in mice. Halberstaedter and Back (*Compt. rend. soc. Biol.*, **126**: 1117, 1937) found that in a group of 23 rats the implantation of a sarcoma terminated the estrous cycle in 20 of the animals in 7 to 31 days. Flaks, Ber, and Pakszuere (*Compt. rend. soc. Biol.*, **128**: 775, 1938) concluded that the inhibiting action of tumor implants on the estrous cycle was not due to an effect on the uterus.

The effect of implants of the Walker Carcinoma No. 256 and the Philadelphia No. 1 Sarcoma on the estrous cycle of the Douredoure strain of rats was studied in this laboratory. Our results, which are not in complete agreement with those noted above, may be of considerable interest to other workers,

for it appears that the inhibiting effect of tumor implants on the estrous cycle may be subject to great variation depending on the tumors and the strain of animals used.

Experimental.

Rats of the Douredoure strain were used. The estrous cycles of the first group of fifteen rats were followed by means of daily vaginal smears for forty-three days prior to tumor implantation. At this time subcutaneous injections of an emulsion of the Walker Carcinoma No. 256 were made on both sides of the abdomen of 8 of the animals. The volume of the inoculum used at each site of injection was 0.2 cc. Subcutaneous injections of 0.2 cc. amounts of a 5 per cent. suspension of casein in distilled water were made on both sides of the abdomen of the 7 control animals. Tumors grew in 5 of the group in which the tumor implants were made. The estrous cycles of all animals of both groups were observed for thirty days following the implantations of the tumors and injections of the casein. At the end of this observation period the tumors in 4 of the rats were large (1 to 2 inches in diameter) and were affecting the health of the animals. In one of the animals the tumors grew slowly and were small at the end of this period. In none of the tumor-implanted animals did the estrous cycle change in regularity or frequency of occurrence. Anestrus followed immediately in one of the 7 rats into which casein had been injected. In none of the other animals was a change in the cycle noted.

At the end of the 30-day period of observation 4 of the rats bearing tumors were eliminated from the experiment because of the large size of the tumors. The two groups of animals were then interchanged with the exception that casein was reinjected into two of the animals of the control group, which was done to keep the two groups of comparable size. The other 5 rats which had received injections of casein at the beginning of the experiment, including the one in which anestrus followed the injection of casein, were given implants of tumors. Tumors grew in three of this group. Three of the group originally implanted with tumors but in which the tumors failed to grow, and one in which the tumors were small, were injected with casein. The estrous cycles were

observed for another period of 26 days. No change was observed in the cycles of the animals which received the tumor implants. The animal which had discontinued the cycle when casein had been injected previously continued in anestrus during this period of observation also. Of the 6 animals which received injections of casein, anestrus appeared immediately in one which died 12 days after the injection. No change was observed in the cycles of the other animals.

In a second experiment 22 rats were divided into two groups of 11 animals each. The animals of one group were inoculated subcutaneously on both sides of the abdomen with an emulsion of the Philadelphia No. 1 Sarcoma. Tumors grew in all of these animals. Those of the control group were injected at the same sites with 1 cc. of a 5 per cent. suspension of rice flour in distilled water. Six of the eleven tumor-implanted animals continued the estrous cycles unchanged during an observation period of 24 days; anestrus occurred immediately in one and four days after implantation in another. One, which was in anestrus when the tumor implants were made but had shown a cycle prior to implantation, continued in anestrus throughout the observation period. Of the 2 remaining tumor-implanted animals, one continued the estrous cycle for 13 days when it died of pneumonia; anestrus occurred immediately after implantation in the other which died 11 days later of pneumonia. Of the control group which received rice flour injections, 5 showed unchanged estrous cycles throughout the observation period. One, which had shown a cycle before the injections but which was in anestrus at the time, continued in anestrus during the remainder of the experimental period. The remaining animals of this group died before the end of the experimental period but had continued the estrous cycle until they died.

Twelve female rats of another group received implantations of the Philadelphia No. 1 Sarcoma when each was in the estrous phase of its cycle. Tumor growth occurred in all of these rats. No change was observed in the estrous cycles of any of them during observation periods varying from 9 to 19 days after the tumor implants were made.

BOOK REVIEWS.

SURGE PHENOMENA, seven years' research for the central electricity board (1933–1940), by the British Electrical and Allied Industries Research Association. 426 pages, illustrations, 23 × 29 cms., London, the British Electrical and Allied Industries Research Association. Price £ 2–10s.

The Central Electricity Board and the electrical industry generally, in England some years ago, recognized the value of research for the purpose of obtaining proved data and information in advance of undertakings of various kinds, thereby eliminating long chances and unproved assumptions by the engineer. The Central Electricity Board in 1933 invited the British Electrical and Allied Industries Research Association to submit proposals showing what profitable work it could undertake of immediate interest to the Board, after which the Board enabled the Association to pursue certain of its proposals on an adequate scale. This book contains the results of the Association's work on surge phenomena covering the period 1933–40.

It opens with a study of lightning, its nature, determination by means of continuously-recording klydonographs certain features of voltage surges on transmission lines, measurement with magnetic links, the point discharge recorder, and a description of an investigation of natural lightning phenomena made in Nigeria during two lightning seasons. Surge propagation is the next major topic and this is followed by surge voltage distribution in transofmers which states theories first and compares theories with results of observed practices. Subsequently the effects of surves on insulation are noted, and a study of protection against surges is made followed by recommendations for the protection of overhead transmission systems.

The work records the study of surge phenomena from every aspect including the development of special portable experimental apparatus. Its thoroughness, accuracy, and care make it a valuable contribution to the knowledge of the subject which will result in further development, greater efficiency and economy.

R. H. OPPERMANN.

ELEMENTS OF ELECTRICAL ENGINEERING, by Arthur L. Cook. 611 pages, illustrations, 16 × 24 cms. New York, John Wiley & Sons, Inc. Price $4.00.

Electrical engineers whose main interests lie in the direction of maintenance and operation well know how important it is to become thoroughly familiar with the practical application of theories and principles. Such knowledge comes from that part of the electrical engineering course which describes the construction and operation of apparatus and machinery, and the contents and characteristics of circuits. The author of this book calls it the elements of electrical engineering. Upon it is built the more specialized and expanded studies leading to analysis and design. But it is valuable in itself in the operations department of industry.

That this book is in its fourth edition is ample testimony as to its popularity. After reviewing electric and magnetic circuits to the extent covered in a pre-

liminary physics course, the book starts with a discussion of direct current machinery. Here the parts, construction, characteristics, efficiencies, ratings etc. are taken up in logical order. Generators, motors, batteries and systems of d.-c. transmission and distribution are covered.

The latter part of the book is devoted to alternating currents, circuits, and machinery. The thoroughness of treatment throughout the entire book as well as the ability to simplify complicated conditions is probably best illustrated in the explanation of polyphase circuits. First the production of polyphase voltages and commercial polyphase systems is discussed, laying the groundwork for system characteristics, then the circuits themselves are taken up including measurement of power in three-phase circuits using three wattmeters and also the two wattmeter method. Alternating current machinery is covered by discussing in order transformers, induction motors, a.-c. generators, synchronous motors, and single phase motors. After this, other somewhat removed topics are taken up such as light and illumination, electrical measuring instruments, and electronic devices. In this latter part of the book there is a chapter on mathematical representation of vectors. As a matter of fact, vectors are used extensively in all of the alternating current sections. The mathematical representation is merely an extension briefly describing methods of representation so that addition, subtraction, multiplication, or division may readily be carried out.

The author recognizes the value of exercises in making the text practical as well as impressionable. Not only are a liberal number of them given but resort is made to their solution in the text proper. The book is invaluable as a text for students in electrical and other engineering subjects. All electrical maintenance and operation men in industry will find here a profitable text and reference work.

R. H. OPPERMANN.

TORSIONAL VIBRATION, by W. Ker Wilson, volume 2, second edition, 694 pages, illustrations, 15 × 22 cms., New York, John Wiley & Sons, Inc., 1941. Price $8.50.

Volume 1 of this work was mentioned in the July, 1941 number of the JOURNAL OF THE FRANKLIN INSTITUTE. Volume 2 is a continuation of that work through the subjects of the determination of stresses due to torsional vibration at resonant speeds, measurement of torsional vibration amplitudes and stresses, analysis of torsiograph records, torsional vibration damping devices, rotating pendulum vibration absorbers, and dynamic characteristics of electrical generating sets direct-coupled to internal combustion engines, and fly-wheel calculations for marine installations. The same care has been exercised in presentation here as in Volume 1. Considerable attention is given to the actual working out of examples which adds so much to the practical value of the book. The same applies to the appendix where there is discussed methods of obtaining the harmonic components of a periodic function.

R. H. OPPERMANN.

ELECTRICAL ENGINEERING FUNDAMENTALS, by Geo. F. Corcoran and Edwin B. Kurtz, 450 pages, illustrations, 16 × 24 cms. New York, John Wiley & Sons, Inc. Price $4.00.

Electrical engineering fundamentals as defined by the authors covers the background of electrical subjects for the study of the specific engineering subjects

of d.-c. machinery and a.-c. circuits. To many of the older engineers this would correspond to the coverage from mechanics, through electricity and magnetism, and part of elementary electricity. Actually, however, the text covers this ground quite completely plus the necessary and applicable portions of physics and electrochemistry which are now so important as basic studies and which, in former years, were either unknown or were not sufficiently known and proved to be deemed valuable. These contribute to make the text a modern one which lays out an up-to-date course in fundamentals.

There are eleven chapters to the book. The first reviews the principles of mechanics upon which the later treatment of electricity is based. Here is considered several of the more basic mechanical quantities both from a conceptual point of view and from an algebraic point of view. With regard to units, the m.k.s. system is used throughout the book, but emphasis is laid on the importance of primary systems of units, and why and how physical phenomena may be described as well in one system of units as in another. In line with the important basic studies mentioned in the previous paragraph, chapter two contains an elementary survey of structure of matter providing the student with a qualitative theory by means of which he may connect many seemingly isolated facts. This is followed by treatments on conductors, insulators and other subjects under the heading of electric charge and permittivity. The treatment then goes into elementary electrostatics, electric current, and d.-c. circuit analysis.

Under the heading of elementary electrochemistry a few typical chemical reactions are considered in so far as they help to explain electrolytic conduction, electroplating, and battery action. Chapter seven gives an exposition of magnetic field concepts leading to a practical definition of magnetic field upon which a reasonably coherent description of electromagnetism can be based. Electromagnetism as applied to electrical engineering is then given attention as well as ferromagnetic circuits. Reverting to the electric circuit the parameters of resistance, inductance, and capacity are discussed and there is illustrated the manner in which these circuit parameters are determined and how they influence circuit performance. The last chapter is devoted to curvilinear-square field mapping.

The test is practical. Wherever necessary, worked-out problems are used as illustrations. Little space is used for other than that directly on the subject, yet the treatment is not too rigorous. Following the pathway of treatment from the beginning there can be noticed a certain individuality of presentation which, once recognized, makes for ease in understanding and an expectancy of logical progression.

R. H. OPPERMANN.

PUBLICATIONS RECEIVED.

Higher Mathematics for Engineers and Physicists, by Ivan S. Sokolnikoff and Elizabeth S. Sokolnikoff, Second edition. 587 pages, 16 × 24 cms. New York and London, McGraw-Hill Book Company, Inc., 1941. Price $4.50.

The American Annual of Photography for 1942, volume fifty-six, edited by Frank R. Fraprie, F. R. P. S., and Franklin I. Jordon, F. R. P. S. 304 pages, illustrations, 19 × 25 cms. Boston, American Photographic Publishing Co., London, Chapman and Hall, Ltd., 1941. Price $1.00.

Gaseous Conductors, Theory and Engineering Applications, by James Dillon Cobine. 606 pages, 16 × 24 cms. New York and London, McGraw-Hill Book Company, Inc., 1941. Price $5.50.

National Research Council, American Geophysical Union, Transactions of 1941. Three Parts, 1035 pages, illustrations, 17 × 25 cms. Washington, The National Academy of Sciences, 1941.

The Identification of Molecular Spectra, by Dr. R. W. B. Pearse, and Dr. A. G. Gaydon, 221 pages, 20 × 28 cms. New York, John Wiley & Sons, Inc., 1941. Price $8.00.

Acoustics of Buildings, by F. R. Watson, third edition. 171 pages, illustrations, 16 × 24 cms. New York, John Wiley & Sons, Inc., 1941. Price $3.00.

Radio Troubleshooter's Handbook, by Alfred A. Ghirardi. Companion Book to (Modern Radio Servicing), 710 pages, 110 illustrations, 22 × 29 cms. New York City, Radio & Technical Publishing Co., 1941. Price $3.50.

CURRENT TOPICS.

Citizens Gas and Coke Utility Builds Tallest Waterless Gas Holder.—ROBERT LATIMER. (*Gas Age*, Vol. 88, No. 7.) The world's tallest waterless gas holder was recently completed in Indianapolis, Ind., by the Koppers Company, Bartlett Hayward Division for the Citizens Gas and Coke Utility. The holder is 394 feet high, 218 feet in diameter and contains 6,400,000 lbs. of steel, and 7,500,000 pounds of concrete. Easily the tallest structure in the Indiana metropolis it contains 12,000,000 cubic feet of gas, and enables the utility to now store 22 million cubic feet, double the former capacity. Completed recently, the holder piston weighs 1,200,000 lbs. and floats on gas of approximately eight inches of water-column pressure. The top has been done in checkerboard orange and white for aviation benefits, the rest of the holder in battleship gray. Incidentally, 4800 gallons of paint were used for the job.

R. H. O.

Fingerprinting Metals.—The art of chemical analysis has drawn its processes from all branches of chemistry and physics. The Industrial Bulletin of Arthur D. Little, Inc., No. 173 points out that its newest acquisition is a combination of chemistry and electricity called electrographic analysis, recently reported at an American Chemical Society convention. The development work was done chiefly at the Bell Telephone Laboratories, to find a simple means for examination of the numerous metallic pieces of a telephone system without injury to them. Electrographic analysis is simple, calls for as little skill as any analytical method, is rapid, and the equipment is cheap. It produces permanent records which, besides their immediate utility, may serve for future reference, for exhibition and legal purposes. At present, electrographic analysis is useful only for qualitative work, and principally for metals. Work is in progress directed toward extending its possibilities. When an electric current flows from a piece of metal into a solution of salt, an alkali or an acid, some of the metal is carried into the solution. Such a small quantity of metal is needed in solution for testing electrographically that the damage to the metal piece is negligible. This is a small-scale and controlled instance of the phenomenon of electrolysis that sometimes does a great deal of

damage by eating away water pipes, car tracks and other metallic objects. The metal removed from the object is identified by the use of chemical reagents of the "spot test" type, such as potassium ferrocyanide to give a blue color with iron or a brown with copper, a sulfide to give a dark-brown color with copper or lead, and dimethyl glyoxime to give a red color with nickel. With the large number of reagents now available, distinctive color tests may be had for practically any metal in the presence of others with which it is likely to be associated. Usually the color is produced at once, but sometimes the "stain" is invisible until it has been suitably developed by exposure to light or a chemical. A simple form of the apparatus is a cell consisting of a small block of aluminum for the lower electrode, or cathode, which is connected to the negative pole of a battery. On top of this is placed a piece of filter paper moistened with the reagent plus a little sodium nitrate or other salt to improve the electrical conductivity. The piece of metal under test is made the anode by connection with the plus terminal of the battery of three or four cells, and held against the filter paper until enough metal is electrically dissolved from it to make the stain on the paper, a matter usually of a small fraction of a minute. With this simple arrangement, most metals and their alloys may be identified, coatings or platings may be inspected for pinholes, and any regular distribution of metal in alloys may be indicated by the diagrammatic print.

R. H. O.

Constant Humidity for 4100 Year Old Bust.—F. N. HOLLINGSWORTH. (*Heating and Ventilating*, Vol. 38, No. 9.) An unusual application of humidity control is to be seen in the Egyptian Department of the Boston Museum of Fine Arts. It is in connection with a 4600 year old limestone bust of Prince Ankh-ha-ef. As Egyptologists know, many limestone objects from Egypt are impregnated with salt which they have absorbed as a result of long burial in the tombs scattered about the country, often covered with sand. When such objects are unearthed and placed in an American Museum, this salt content is likely to cause their disintegration. In fact many valuable objects stored away have been totally destroyed this way. In Egypt a condition of relatively low, stable humidity prevails. In Boston, with its frequent east winds blowing in directly from the Atlantic, the weather is characterized by great and often abrupt changes in humidity. Since salt attracts moisture, the salt-impregnated limestone objects in the Egyptian Department first absorb moisture in damp weather and then give it

off in dry periods. This results in the breaking down of the surface of the stone and in extreme cases, total disintegration. So the Museum's engineer and Dows Dunham, curator in the Egyptian Department, devised an apparatus to create for the bust, under a glass case, an artificial atmosphere in which the variations in humidity would be entirely eliminated, the relative humidity kept constant and thus allow the salt to be dormant. The case is connected by piping to a box of calcium chloride, a powerful moisture absorbent. A pump circulates the body of air in the case through the box. A gauge gives the relative humidity content of the air surrounding the bust at all times. Relative humidity is fixed to be kept at 30 per cent. A miniature gasometer connected by a tube with the inside of the case equalizes atmospheric pressure with the air outside.

R. H. O.

Diesel-Electric "Prospectors" for Mountain Service.—(*Electrical Engineering*, Vol. 60, No. 11.) Two self-powered cars, Diesel-electric driven, make up a new kind of train which the Denver and Rio Grande Western Railroad recently put into operation between Denver, Colo., and Salt Lake City, Utah. Called the "Prospectors," these small trains, with a capacity of 62 passengers, contain the full range of accommodations provided in full-length trains. Designed and built by the Edward G. Budd Manufacturing Company, each car is 75 feet long and weighs approximately 130,000 pounds ready to run. Two more cars may be added to each train if desired. Two Diesel engines suspended beneath each car supply power, each engine driving a generator which in turn feeds two of the four propulsion motors on the car. The engines, each rated at 192 horsepower at the top operating speed of 1,600 r.p.m., are six-cylinder four-cycle full Diesel engines of the horizontal type. They are started by special windings in the traction generators, no separate starting motors being required. The motors are truck-mounted, co-supported by axle through the gear case and by spring at motor end, drive being by means of spiral bevel gears. Control is entirely by means of the throttle and fuel supply of a variable-speed governor, increased engine speed producing greater horsepower at the Diesel shaft and consequently increasing the electric energy supplied to the motors. To insure engine performance at each governor-controlled speed, an Amplidyne control is employed, which uses a small tachometer generator driven by belts from the engine. Constant horsepower at all altitudes is maintained by a normalizer, belt-driven from the traction generator, which keeps air in the intake manifold at constant pressure. Brakes are of a newly

developed type having blower-cooled braking disks bolted to the wheel hubs and composition-lined shoes. The cars are cooled by electromechanical air-conditioning equipment, using Freon refrigerant. Car heating is by engine-jacket water, by which a temperature of 70 degrees can be maintained with outside temperatures as low as −40 degrees and engines at idling speed.

R. H. O.

The Essential Auto.—An editorial in *Compressed Air Magizine*, Vol. 46, No. 10, states that during a recent cessation of street-car and bus service in Detroit, business went on pretty much as usual and no manufacturing plant engaged in defense work was obliged to close. Those among the city's 1,600,000 residents who had to get to and from work, go shopping, or move about for any other reason, turned to private cars for transportation, and these handled the problem with amazing efficiency. Detroit is fortunate in that the ownership of private automobiles averages one car for every 3.7 persons. The Detroit incident emphasizes the fact that passenger automobiles are no longer primarily used for pleasure. On week-ends and holidays, people still do much unnecessary motoring, but the average car is principally driven for purposes connected with earning a livelihood or with ministering to the economic and social necessities of the family. These statements are borne out by the results of surveys conducted by the Automobile Manufacturers Association. The findings were assembled from official records compiled by the U. S. Government and the highway authorities of several states. They show that the nation's cars amass an annual total of 498,000,000,000 passenger miles of travel and make approximately 15,000,000,000 round trips. More than half the mileage and three fourths of the trips come under the head of "necessity" driving. Ninety-six out of every 100 automobiles on the road are used a considerable part of the time for non-pleasure. As a class, traveling salesmen cover the most ground, averaging 18,791 car-miles a year, or more than double the average per year for all drivers. Doctors are second, with an average annual mileage of 12,932, and they make the greatest number of round trips, 947. Farmers, industrial workers, and construction men are the leading owners of automobiles among occupational groups, but they make relatively short runs and their annual mileage is comparatively small. Nearly two-thirds of the cars used by wage earners are more than two years old and 32 per cent. of them are more than six years old. The survey shows that the older a car is, the less it is driven.

R. H. O.

No True "Dry Rot."—There is no real "dry rot" that attacks wood and causes it to decay. Wood must contain more than 20 per cent. of moisture before fungi can grow on it. What is ordinarily called "dry rot" is caused by one of a few species of fungi that grow rootlike strands that serve as pipelines through which they draw into dry wood the water they must have to live and to destroy the wood. These rootlike strands must reach moist soil or some other source of moisture if the "dry rot" is to cause decay of the wood, say U. S. Department of Agriculture scientists who have studied the various forms of wood destruction. Wood kept dry, they emphasize, is a permanent building material. One way to prevent decay of wood is to inject into it preservative chemicals that prevent fungus growth. The other way is to keep it dry so that fungi cannot live. Even the "dry rot" fungi cannot develop if water can be kept beyond their reach.

R. H. O.

Coal Mine Rock Falls.—Falls of rock resulting from the disintegration of exposed rock strata in the roofs of coal-mine entries, which always have been a serious accident hazard as well as an economic burden, are due primarily to changes in the humidity of the air entering the mine, it is indicated in a study recently made by the U. S. Bureau of Mines (Report of Investigations 3588). Tests made on draw slate immediately overlying the coal, which was taken from the Bureau of Mines' experimental mine at Bruceton, Pa., show that changes in temperature of the order common in most coal mines have very little effect on the rock in the roof, but that changes in humidity create considerable stresses and strains which cause the rock to break up and fall. During the cold winter months, the Bureau's experimenters state, these rocks dry out in the mine roof. With the advent of spring and summer weather, warm humid air enters the mine, moisture is deposited on the rocks and causes the clay constituents thereof to swell, thereby weakening and disintegrating them. Coals, on the other hand, are hardly affected by ordinary variations in humidity but are subjected to somewhat greater stresses than shale rock by changes in temperature. It is unlikely, however, that the ordinary temperature changes encountered in most mines could lead to mechanical failure of coal strata. The Bureau of Mines study was undertaken not only to determine the causes of rock behavior in mines, but also to develop, if possible, means for reducing rock falls caused by changes in weather conditions. It has thus far been determined that sealing the roof surfaces with coal-tar base paints or with gunite

is helpful, and investigations are being made of the possibilities of air conditioning in mines as a preventive measure. Experiments also will be conducted on rock strata in mines other than the Bruceton mine and of a nature other than those generally found overlying the Pittsburbh coal bed.

R. H. O.

Underground Parking Aids Traffic Handling in Buenos Aires.—F. A. ZAMBONI. (*Engineering News-Record*, Vol. 127, No. 17.) Three years ago the first two municipal underground parking lots in a program contemplating a total of eight such traffic relief facilities were placed in service in Buenos Aires. These two initial units, with a capacity of 756 cars, have proved a distinct aid in relieveing traffic congestion, and their operation, which includes a mechanical ventilation system, has shown that such facilities can be made self-liquidating through a small parking fee (about 15 cents) and rents from sales rooms, repair shops and poster advertising. Because the results have been so satisfactory it is hoped that the entire program, providing accommodations for 6,770 cars can now be completed. The first two subterranean parking garages were built in connection with the widening of the Avenida Nueve de Julio for which a strip of old buildings a block wide and five blocks long was removed; eventually it is planned to extend this tree-lined boulevard completely across the city, but the expense will be large since the work so far completed, including the underground parking garages cost over $6,000,000 (U. S.). The commercial area of Buenos Aires, where traffic congestion is greatest, is located on the rim of the city, rather than near the geographical center, as is the case in many cities. Subway lines radiate in three directions from this commercial area, and it is on these lines near the limits of this area where the remainder of the parking facilities are to be built. The two existing parking garages, however, are almost in the center of the commercial area. Both are 200 ft. wide. One is 800 ft. long, the other 400 ft. Ramps, each made up of three 11 ft. lanes, give access to the garages on either side; experience in operation has indicated that two lanes would have given ample capacity. The garage structure is of reinforced concrete, columns with flaring capitals carrying 18 in. deep flat slab panels 20 × 25 ft. in plan. The ceiling height in the garages is 15 ft. Although these garages are all on one level, several of two-story type are planned for the future program.

R. H. O.

Chinese Engineers Build New Highway Network.—(*Roads and Streets*, Vol. 84, No. 9.) Engineers in Free China in the past four years have constructed 80,000 kilometers of modern roads through previously untouched and isolated wastelands, giving China vital new lifelines needed for development of her new economy, and for communication with the East and the Western world according to information received by United China Relief. All these roads have been built in the vast, remote provinces of China, which before the present war were as undeveloped economically and industrially as our own West in the 1850's. This monumental task has been accomplished with road gangs of farmers, soldiers, and peasant women. China's West had remained in a dormant state for centuries because of high mountain ranges which presented formidable transport problems and because the rivers of China, although numerous, were too swift flowing or required extensive diking to make them navigable for boats other than junks or sampans. Within a year after Japan entered China proper in July 1937, China lost 90 per cent. of her industries that were centered in the rich coastal provinces. Faced with economic defeat, her coolies moved 385,000 tons of industrial equipment into the interior, 1500 miles away, in one of the epic migrations of history. And the backward West, rich with undeveloped natural resources, full of fertile grazing lands, rich forests and uncultivated farming soil, was "discovered" by a government and nation to which the West was previously known only in legend. Development of China's West, faced an initial setback because of a total lack of modern roads and transportation facilities. But taking part in the migration of industry was the bulk of Chinese engineers—some 3000 of them. All engineers were immediately mobilized by the Chinese Government, and road building to speed the moving of troups, material and supplies was undertaken as a first major defense project.

R. H. O.

Glass Window Replacement Fabric.—C. H. S. TUPHOLME in *News Edition*, American Chemical Society, Vol. 19, No. 20, states that very few glass windows smashed in air raids are replaced by glass. As a rule a special window fabric, consisting of wire mesh or cotton net impregnated with cellulose acetate plastic, is nailed on wooden battens and fixed in the window frame. It has become general practice with large broken plate-glass windows to fill the window with ply, with a small glass window giving prospective customers a view of the wares within. The general method of manufacturing window replacement fabric consists in the passage of a loosely woven fabric (suitably prepared to give it rigidity, etc.)

through a dope of cellulose acetate and plasticizers. The fabric is immersed in the dope and is withdrawn at a slow rate. Preliminary drying of the solvent takes place while the fabric is held vertically in a warm-air tower. Later the finished fabric is more fully dried or seasoned by a protracted drying on cloth while being passed slowly over heated cans. The material is a loosely woven type with an open network structure. It is bleached and finished with either starch or dextrin in order to dress it properly and to give it sufficient rigidity or structure during the later impregnation process. It is also advisable that the fabric be as dry as possible at this stage as any residual moisture tends to give resets blushing during the drying of the dope. Cellulose acetate is the usual basis for the plastic film which is applied to the fabric. If this material be used alone—i.e. without the addition of softeners or plasticizers—a very hard, brittle film results which shows poor aging properties. Consequently additional material is added to give the finish a certain amount of flexibility and good aging properties. Dimethyl Phthalate and Triphenyl Phosphate are products found to be most suitable

R. H. O.

12,000,000 More Pounds of Aluminum.—(*Iron Age*, Vol. 148, No. 17.) On Monday, Oct. 13, at Glenville, N. C., the governor of that state pressed a button which put into operation the newest hydro-electric power project of the Aluminum Co. of America. Nestled in the heart of the Great Smokies, on a tributary of the Little Tennessee River, this Glenville plant of the Nantahala Power & Light Co., of Franklin, N. C., will now add 27,000 kva. to the power available for making aluminum in the Alcoa, Tenn. plant of the parent company. Glenville and Nantahala are both members of the Nantahala Power and Light Co., which is a wholly owned subsidiary of the Aluminum Co. of America. Aluminum is truly an electrical metal as well as a strategic one. Electric power is is one of its chief ingredients and the 30,000 h.p. now being converted at Glenville will mean the production of 12,000,000 more pounds of aluminum per year. The Glenville project, in addition to setting a record for construction speed (it was started July 1), also has the distinction of having the highest head of any hydro-electric plant east of the Rockies. The drop from water level in the dam to the impulse wheel in the plant is 1150 ft., giving an effective water pressure at the nozzles of well over 500 lb. per sq. in. The length of the pressure content bringing the water from the dam to the power house is a little more than three miles. Construction

of this enterprise in the time taken is doubly remarkable when one considers the difficulties of such work undertaken in the virgin heart of the Great Smokies. Availability of the sites for Glenville and Nantahala was due to the foresight of the Aluminum Company in planning future expansion which led it in 1910 to a survey of power possibilities on the Little Tennessee River, and its tributaries and which was followed by the acquisition of riparian rights in this district. Previous to the demands of the defense program three hydro-electric projects had been completed in this district by the Aluminum Company for supplying power to its Alcoa plant.

R. H. O.

Bottleneck in Burlap.—Gunny sacks have nothing to do with guns, but they represent one of the problems of the Office of Agricultural Defense Relations. On farms burlap gunny sacks or "croakus" bags are two-way carriers. Feeds, fertilizers, chemicals, and other things come in them; wheat, potatoes, onions, and cabbage go. The material covers cotton bales and other farm products sent away to market. Normally, agriculture uses more than a billion and a quarter yards of textile packaging material a year, most of it burlap. Burlap is made from jute, imported chiefly from India, and shortage of shipping threatens importations. Looking ahead towards agriculture's effort to meet increasing demands for food, the Office of Agriculutral Defense Relations believes that cotton bagging might take the place of much of the burlap. To economize in shipping we should expand the use of cotton bagging, and so prevent an acute shortage of burlap. The practical difficulty is that the cotton mills are already loaded with defense orders—orders that require the same type of machinery necessary to turn out the bagging materials agriculture wants. The Office of Agricultural Defense Relations has asked the cotton textile industry to explore the possibility of producing more heavy sheetings and osnaburgs, already used to some extent as textiles for packaging. Meantime it urges farmers to take good care of bags now in use, repairing them to make them last longer and keeping them "in circulation" with quicker returns to dealers.

R. H. O.

Electric Alloy Steel.—Construction of the first plant in the country specifically designed for the production of electric alloy steel was recommended recently by Director-General William S. Knudsen of the Office of Production Management. The proposed plant, to be located at South Chicago, will be operated by the

Republic Steel Co., according to a report by W. A. Hauk, steel consultant, upon which the recommendation was based. It will have a capacity of 504,000 tons of alloy steel ingots annually, producing 317,000 tons of parts for aircraft and ordnance use. The proposed plant is unusual, according to the report, in that it is the first in the country in which every unit from ore to finished product will be designed to produce electric furnace alloy steel. Among the advantages listed are the fact that ample power already is available and a trained operating and supervisory force at hand. It is estimated that the first units of the plant can be in operation in eight or nine months and the entire plant going in about fifteen months. The first step in the proposed operation is the development of a coal mine at Elkhorn, Kentucky, to produce coking coal for the plant. Shipment of ore and transportation of finished products could be carried out by Great Lakes carriers relieving rail facilities in the district, the report says. It is pointed out that practically all the nation's electric alloy steel production now is being used for defense manufacture and increases in this field are of utmost importance.

R. H. O.

Infra-Red Used for Shrinkage Fit.—(*Electrical World*, Vol. 116, No. 22.) Rejects frequent in press fitting of aluminum and steel parts have been reduced by using infra-red heat for shrinkage fit. In the Westinghouse small motor plant at Lima, Ohio, a rotary conveyor traveling at the rate of 30 ft. per minute carries aluminum motor frames through a tunnel formed by a battery of 56 375-watt lamps. The aluminum frames are heated to 150 deg. C., which expands the 6¾ in. bore 0.020 in., enough to allow the wound primary to drop in place. Using the infra-red heating method as suggested by Fred C. Gossett, supervisor of methods, tools and equipment, the shrink fit allowance is much larger than that practical for a press fit. Until this method was discovered the mechanical operation of obtaining proper fits between hard and soft metal parts had always been more or less unsatisfactory.

R. H. O.

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